CONNECTICUT DEPARTMENT OF TRANSPORTATION
Reconstruction of I-84
Washington Avenue to Pierpont Road
Waterbury, CT
ConnDOT Project No. 151-273
Federal Aid Project No. NHI-84-2 (172) 33

FINAL SCOUR REPORT
BRIDGE NO. 05774

EASTERLY I-84 CROSSING
OVER THE MAD RIVER

Waterbury, Connecticut
New Haven County

Prepared By:

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July 2006
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Executive Summary

This scour report has been prepared for the final design of proposed Bridge No. 05774, the easterly I-84 crossing over the Mad River. This bridge is one of six (6) waterway crossings over the river to be constructed under the State Project No. 151-273, improvements to Interstate 84 in Waterbury from Washington Avenue east to Pierpont Road. The subject 4.3-kilometer (2.7 mile) long highway project has been designed by Ammann & Whitney (formerly Berger, Lehman Associates, P.C. – BLA).

The project proposes shifting the horizontal alignment of I-84 roughly 60 meters (200 ft) southerly from its current location. Consequently, the proposed bridge will be constructed approximately 150 meters (along the relocated river; 500 ft) downstream of the existing crossing. The new crossing is also located within the limits of a proposed relocation of the Mad River (see *River Relocation Report, Mad River, Beaver Pond Brook*).

The proposed hydraulic clear span (measured perpendicular to the river baseline) will be increased from 15.7 meters (51.5 ft) to 26 meters (85.3 ft). The proposed bridge width, along the river baseline, will also increase from 31 meters(102 ft) to 57 meters (187 ft) to accommodate roadway widening.

The proposed bridge will provide a minimum of 0.8-meter (2.6-ft) underclearance to the 100-year design flood elevation with virtually no backwater toward upstream. In the case of the 500-year flood, the underclearance nears zero, but it is still hydraulically adequate to convey the flow.

This report finds that the proposed bridge will experience the greatest potential scour during the 500-year event. The computations indicated the depth of scour at the bridge could be as much as 2.2 m (7.2 ft). The piles supporting the substructure will not be exposed by the scour. The analysis is based on the existing streambed material that is found in the vicinity of the proposed bridge. The proposed channel under the bridge will, however, have Standard Riprap on the banks providing added protection.

Table 1. NBIS Ratings and Scour Related Design Information

Recommended NBIS Item 113 Rating	8 (for 100-year design discharge)
Recommended NBIS Item 71 Rating	9
Recommended NBIS Item 61 Rating	8
Scour Risk Designation	Low Risk
Depth of Potential Scour (500-year)	2.19 m (Abutment #1 – West); 2.06 m (Abutment #2 – East)
Foundation Type	Abutment Footings on Piles
Recommendations	Foundation Designed for Predicted Scour

Reference Reports

The following reports, prepared under separate covers for the project, should be referenced for more detailed information pertinent to the hydrology and hydraulics for the subject reach of the Mad River and the hydraulic design of Bridge No. 05774.

- *Overview Report for Hydraulic Design, CT DEP Flood Management Certification & FEMA Conditional Letter Of Map Revision (CLOMR), Mad River & Beaver Pond Brook, Waterbury, Connecticut* prepared by ConnDOT, July 2006.
- *Hydrologic Report, Mad River* prepared by BLA, September 1999
- *Hydraulic Analysis for Design Report, Mad River* prepared by ConnDOT, revised April 2014.
- *Final River Relocation Report, Mad River & Beaver Pond Brook* prepared by BLA, January 2004 and revised by ConnDOT, April 2006.
- *Mad River Floodplain/Floodway Analysis Report for FEMA CLOMR & CTDEP Flood Management Certification* prepared by ConnDOT, revised April 2014.

Project Overview

The information presented in this report are mostly derived from the hydraulic analyses performed using the DOT "Design" discharges as presented in the *Hydraulic Analysis for Design Report, Mad River* prepared by ConnDOT, revised April 2014. For complete hydrologic information refer to *Hydrologic Report, Mad River* prepared by BLA (Ammann & Whitney), September 1999. The summarized hydrologic information is shown in the table below.

Table 2. Hydrologic Information

Watershed Area:	62.26 km^2 (24.04 mi^2)- Large Structure
Discharges:	100-Yr: 176.98 cms (6,250 cfs)
	500-Yr: 269.01 cms (9,500 cfs)
	Overtopping: >500 year

See the Overview Report referenced above for an overview of the project, the existing and the proposed project conditions.

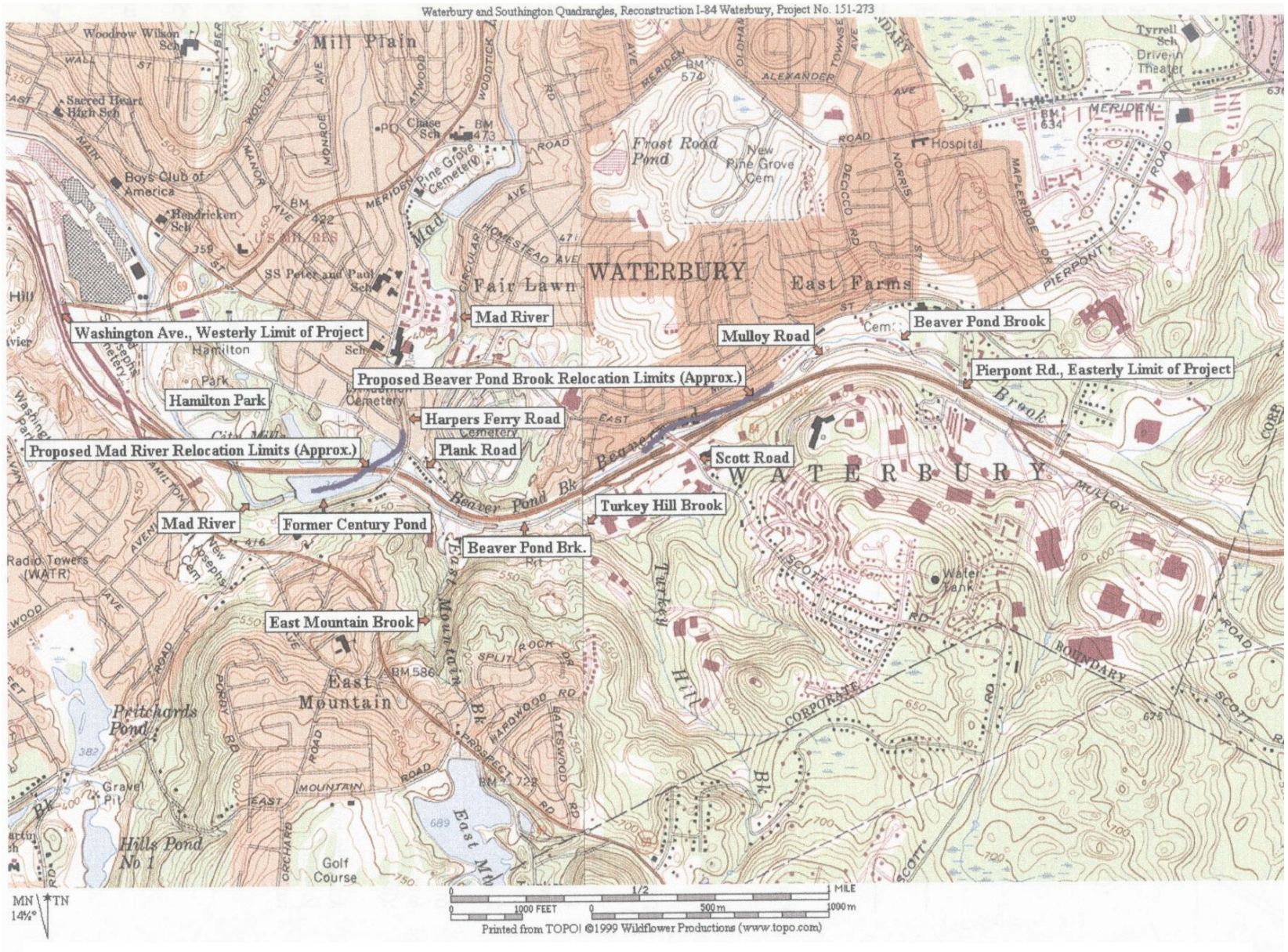


FIGURE 1 - PROJECT LOCATION PLAN

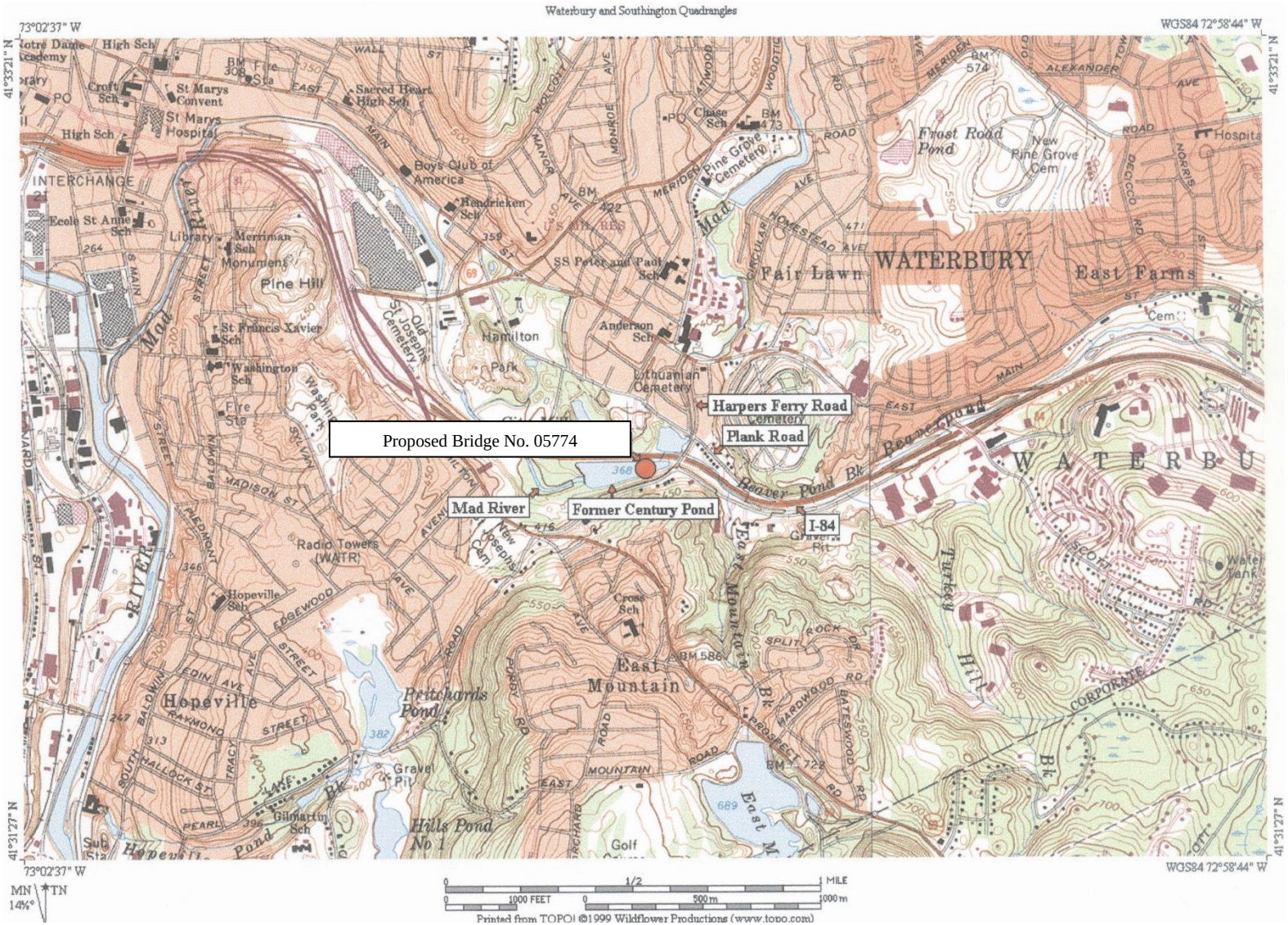
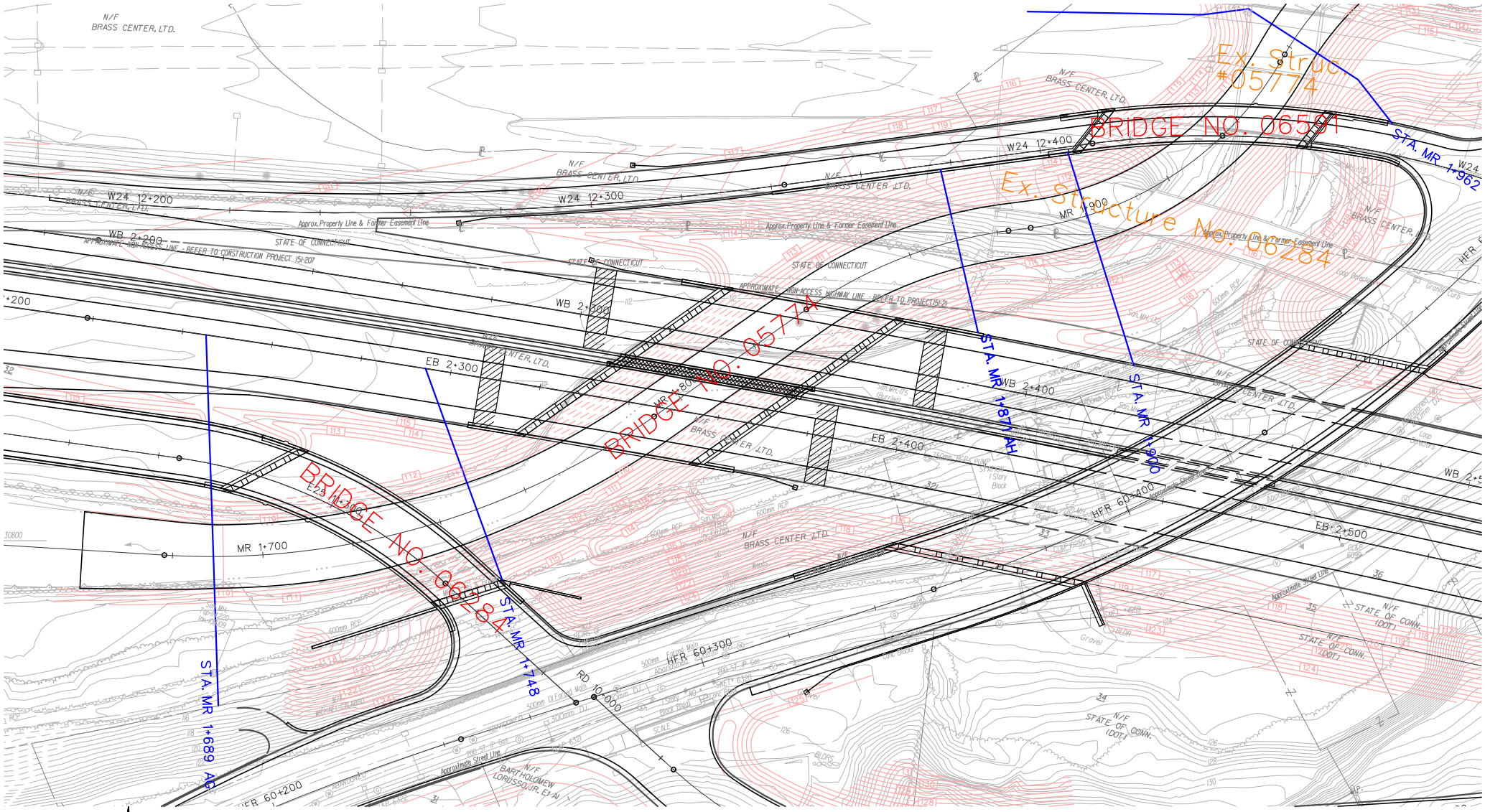


FIGURE 2 - STRUCTURE LOCATION PLAN



CONNECTICUT COORDINATE GRID

NAD 1983

PROPOSED BRIDGE NO. 05774 OVER MAD RIVER

CROSS SECTION LOCATION PLAN

I-84 Waterbury, Project No. 151-273 (In State Plane Coordinate System)

SCALE IN METERS

0 10 20 40

FIGURE 3 - CROSS SECTION LOCATION PLAN (VICINITY OF BRIDGE)

Report Background

This scour report with the accompanying final hydraulic report have been prepared as part of the final design for Bridge No. 05774, the easterly crossing of Interstate 84 over the Mad River. The proposed structure is located approximately 150 meters (500 ft) downstream (along the relocated river) of existing I-84 Structure No. 05774. This relocation is needed to accommodate a 60-meter (200-ft) southerly shift/realignment of I-84 in this area to improve the horizontal geometry of the highway. The new crossing is located within the limits of a proposed relocation of the Mad River.

Scour depths have been estimated following procedures set forth by the Federal Highway Administration in Hydraulic Engineering Circular No. 18 (HEC-18), *Estimating Scour at Bridges*, May 2001. As recommended on page 9.B-2 of the *2000 ConnDOT Drainage Manual*, the following Amended Local Abutment Scour Equation was utilized:

$$Y_s/Y_a = [2.27\ K_1\ K_2\ (L'/Y_a)^{0.43}\ Fr^{0.61}] + 0.05 \qquad \text{(ConnDOT)}$$

This equation predicts scour depths for the 50th percentile as compared to the more conservative HEC-18 version of Froehlich's equation (equation 7.1, page 7.8), which would have encompassed 98% of the laboratory produced scour holes from the original study. The HEC-18 version of Froehlich's equation is as follows:

$$Y_s/Y_a = [2.27\ K_1\ K_2\ (L'/Y_a)^{0.43}\ Fr^{0.61}] + 1 \qquad \text{(HEC-18)}$$

A comparison of the two local abutment equations shows that ConnDOT's version will predict scour depths $0.95Y_a$ less than proposed by HEC-18. Y_a is the average depth of floodplain flow at the upstream approach cross section.

The discharges used in this investigation have been approved by ConnDOT and are presented in the September 1999 *Hydrologic Report, Mad River, Waterbury, Connecticut* prepared by BLA (Ammann & Whitney). The discharges reported in the original 1979 and currently effective 2013 Waterbury Flood Insurance Studies are 25-30% lower than those approved by ConnDOT.

The hydraulic analysis completed for this investigation utilized HEC-RAS version 4.1.0 assuming mixed flow conditions. A CD containing the HEC-RAS data files is included in the referenced *Hydraulic Analysis for Design Report, Mad River*.

To avoid confusion between existing and proposed crossings in the report, the existing crossing is referred to as "Structure" followed by the ConnDOT bridge number, whereas the proposed crossing is called out as "Bridge" (e.g. existing Structure No. 05774 versus proposed Bridge No. 05774).

Proposed Bridge

The new Bridge No. 05774 will be a single span, welded steel plate girder bridge with a clear span of 26 meters (85 ft), as measured perpendicular to the abutment faces. The substructure will consist of concrete abutments founded on end-bearing H-piles terminating in glaciofluvial deposits. The width of the structure will be 57 meters (188 ft) measured along the river baseline, or 40 meters (132 ft) measured perpendicular to the roadway baseline. To reduce impacts to photosensitive fish species along the width of the bridge, grated openings will be provided along the highway median to allow sunlight penetration. The proposed bridge is located at River Station 1807.5 in the Proposed Condition hydraulic model, within a 520- meter (1,706-ft)reach of the Mad River which is to be relocated.

The new southerly shifted I-84 alignment will traverse the former City Mills Pond approximately 200 meters upstream of Century Dam. The dam was actually partially breached in 1998. Prior to the breach, City Mills Pond extended upstream through the existing I-84 crossing (Structure No. 05774), terminating approximately at the downstream side of the next upstream roadway crossing (Plank Road Structure No. 05668). After draining the pond, the channel immediately upstream of the breached dam was apparently provided with riprapped channel banks for a length of approximately 130 meters (425 ft). Upstream of this segment to roughly the midpoint between the existing Structures No. 06284 and No. 05774, the existing channel shows signs of erosion along the riverbanks displaying lateral instability of the river caused by the breach of the dam. The riverbanks are actively eroding, forming several shallow meanders. The erosion is beginning to encroach into a reported bulky landfill site which was apparently active during the dam breach project. The source of the landfill material is purportedly from the development of the Brass Mill Mall site in Waterbury. In order to prevent the erosion in the post-project condition, the channel will have riprapped side-slopes of 2H to 1V with a bottom width of 12 meters (40 ft) in the vicinity of the proposed bridge. The riprap protection should also eliminate the lateral instability of the river.

The overall vertical profile of the relocated channel will be maintained by a series of strategically placed riprap grade control structures. The general concept of the grade control structures is from the 1986 Swiss publication *Blockschwellen* (Block Ramps) by Whitttaker and Jäggi. These structures will serve as hard-points along the channel bottom to limit channel headcutting. Between the grade control structures, 600 mm (24 in.) of Gravel Streambed Material will be placed along the channel invert to simulate a "natural" riverbed. This substrate will maintain the continuity of sediment supply through the reach, similar to a natural channel. The gravel material will also serve as a foundation for the development of a diverse and productive aquatic habitat.

As the geometry of the river will be changed, exact comparison of the flood elevations to the existing condition at the proposed bridge site is not possible. Nevertheless, the locations of the upstream and downstream faces of the bridge are considered most comparably to the Cross Sections 1837 and 1778 respectively of the Existing Condition hydraulic model. Comparing the 100-year water surface elevations at these locations, the results indicate that, even with the placement of a new waterway crossing where none currently exists, the design flood profile will be mostly lowered with only a slight increase at the upstream end. The computed differences were 0.02 m (0.07 ft) increase and 0.28 m (0.92 ft) decrease for the upstream and downstream faces respectively. This can be attributed to the proposed gradient of the relocated river which will be on a constant downgrade. In the existing condition, downstream of these sections the river is on an adverse grade (upward gradient) potentially causing more energy loss. As the flow approaches the adverse grade the flood profile becomes flat (a constant elevation) through these sections. The flat versus on-grade profiles produced the increase and decrease over the segment.

The 100-year flow will pass through the bridge with minimal constriction resulting in a minimum underclearance of 0.8 m (2.5 ft), which is to the low chord at the downstream-westerly end of the structure.

For the 500-year flow, the water surface elevation will increase by 0.58 and 0.13 m at the upstream and downstream faces respectively. These increases may be explained by the channelization of the river section which narrows the width of the flood resulting in the rise of the water surface. There will also be some head losses due to the obstructions caused by the abutments. Furthermore, the water surface will come partially in contact with the low chord, without causing surcharging onto the roadway. This is an improvement compared to the existing I-84 bridge where the 500-year flood would surge onto the highway.

The flow velocity through the bridge opening will be 3.0 m/s (9.8 ft/s) and 3.42 m/s (11.2 ft/s) respectively for the 100- and 500-year discharges.

Approximately 40 meters (130 ft) downstream of the proposed I-84 crossing, another waterway crossing will be constructed which is the relocated Bridge No. 06284, the I-84 Eastbound Exit 25 Off-Ramp over the Mad River. Although the off-ramp bridge is located in close proximity, the backwater resulting from the 100-year discharge does not extend upstream to the proposed I-84 Bridge No. 05774. However, the proposed water surface profile through the proposed Exit 25 Off-Ramp crossing will be higher than the existing condition.

Toward upstream to the existing easterly I-84 crossing site or the proposed Westbound Exit 24 On-Ramp Bridge No. 06591, the proposed 100-year water surface profile will again be higher than the existing condition by as much as 0.57 m (at Section 1900). This is due to the river relocation work in which the stream flow will be constricted to the proposed trapezoidal channel.

Scour Potential Assessment and Results

Scour computations were completed for the 100-year Design and 500-year Check frequency discharges. The computations for the lower frequency discharges were not performed as the degree of contraction, velocity and other flow variables were found relatively moderate compared to the conditions under the above high frequency discharges.

The estimate of D_{50} was based on a soil sample of existing material taken in the vicinity of the proposed bridge (see Figure 4). The bottom of the proposed channel will actually be laid with Gravel Streambed Material which is intended as sediment supply medium, as indicated previously. However, the composition, thickness and the relative vertical location of this layer will change over time, as it is displaced and replenished with the sediment supply from upstream - mainly until the proposed channel stabilizes, and a balance in sediment transport is established. Moreover, as the median particle size of the proposed channel-bed material is larger than that of the soil sample, the d_{50} used in the computation is deemed to produce more conservative results.

Figure 4. Soil Sample (For estimating D_{50} for Scour Analysis)

Scour analysis Soil Sample #2 in vicinity of Station MR 1+720, northerly riverbank looking downstream, 12/7/00

The computed scour depths are minimal for discharges up to and including the 100-year event. This is because the abutments have been located so as to minimize the obstruction of overbank floodplain flows and the river channelization reduces the contraction of flow through the structure.

Computed scour depths for the 100- and 500-year return frequencies are as follows:

Table 3. Summary of Computed Scour Depths

100 Year	Scour Depths (m)			
	Long-Term	Contraction	Amended Abutment	Amended Total
Abutment 1(Westerly)	0.9	0.18	0.00	1.36
Abutment 2(Easterly)	0.9	0.18	0.00	1.36

500 Year	Scour Depths (m)			
	Long-Term	Contraction	Amended Abutment	Amended Total
Abutment 1(Westerly)	0.9	0.55	0.73	2.18
Abutment 2(Easterly)	0.9	0.55	0.60	2.05

Long-term channel scour was assumed to be 0.9 meter (3 ft) to account for potential future channel degradation and will largely be controlled by the proposed riprap grade control structures. As discussed previously, the general concept of the grade control structures is from the publication *Blockschwellen* by Whittaker and Jäggi. The design assumes that the structures will act as hard-points along the channel bottom to limit channel headcutting. As scour holes develop downstream of the grade control structures, rocks from the grade control structures will launch into the scour holes. Eventually, equilibrium will be reached when a sufficient quantity of stones has been launched into the scour holes, completely armoring the holes, and preventing further channel degradation. The volume of the constructed grade control structure must be sufficient to provide enough rock to launch into the scour hole to an adequate depth to armor the scour hole and still provide grade control protection in its constructed location. The thickness of the proposed grade control structures (River Stations 1+860, 1+775 and 1+695) is 2 meters (6.6 ft) with a length, along the river baseline, of 6 meters (20 ft). It is assumed that the anticipated launching of the rocks could reduce the thickness of the grade control structure by as much as 0.9 meter (3 ft) and result in a corresponding lowering of the constructed channel profile (long-term channel degradation).

Structural Design Review and Conclusions

Footing
Page 2.4 of HEC-18 states:

> Placing the top of the footing or pile cap below the streambed a depth equal to the estimated long-term degradation and contraction scour depth will minimize obstruction to flood flows and resulting local scour.

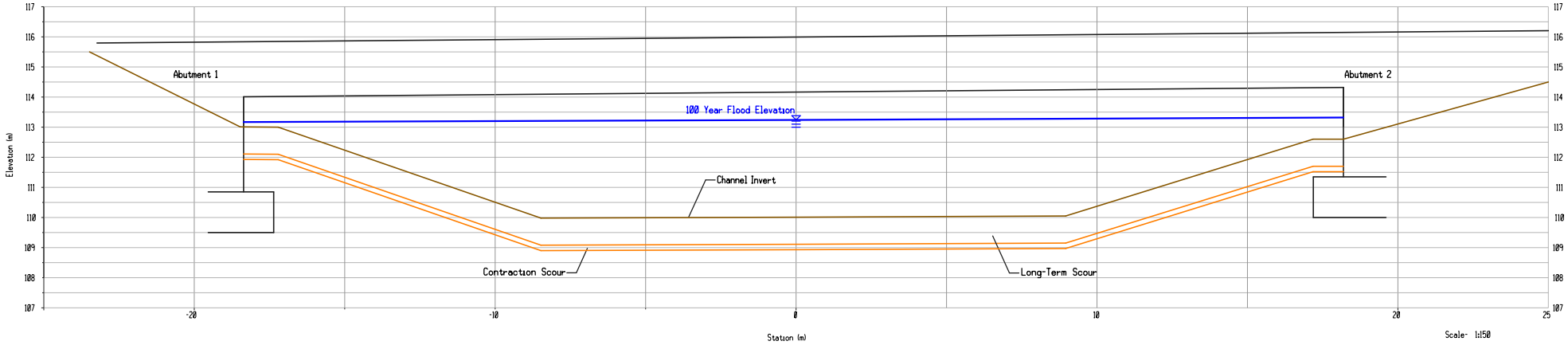
The top of the pile cap has been located in accordance with this guideline for the-100 year design discharge.

Piles
The typical guideline for pile supported abutments is to design the substructure using normal factors of safety assuming the piles are unsupported to the depth of total scour (long-term plus contraction plus amended local abutment) for the design discharge. The calculations indicate that the depth of total scour will not expose the piles for the-100 year design discharge.

"Superflood"
Page 2.4 of HEC-18 recommends that the foundation design should be checked for scour conditions resulting from a "Superflood". The design "should have a minimum factor of safety of 1.0 (ultimate load) under the superflood conditions." For this bridge the 500-year flood was assumed to be the "Superflood". As with the 100-year discharge, the estimates predict that the piles will not be exposed by scour during the 500-year discharge. Although the maximum estimated scour depth is greater at Abutment #1 (western abutment), the worst case condition will occur at Abutment #2 (eastern abutment) because of its shallower depth of cover over its footing. The footing will potentially be exposed by the 500-year flood.

Figure 5a. Scour Depth Cross Sections

Proposed I-84 Bridge No. 05774, Section Along The Upstream Face, I-84 Waterbury Project 151-273, Mad River



Proposed I-84 Bridge No. 05774, Section Along The Upstream Face, I-84 Waterbury Project 151-273, Mad River

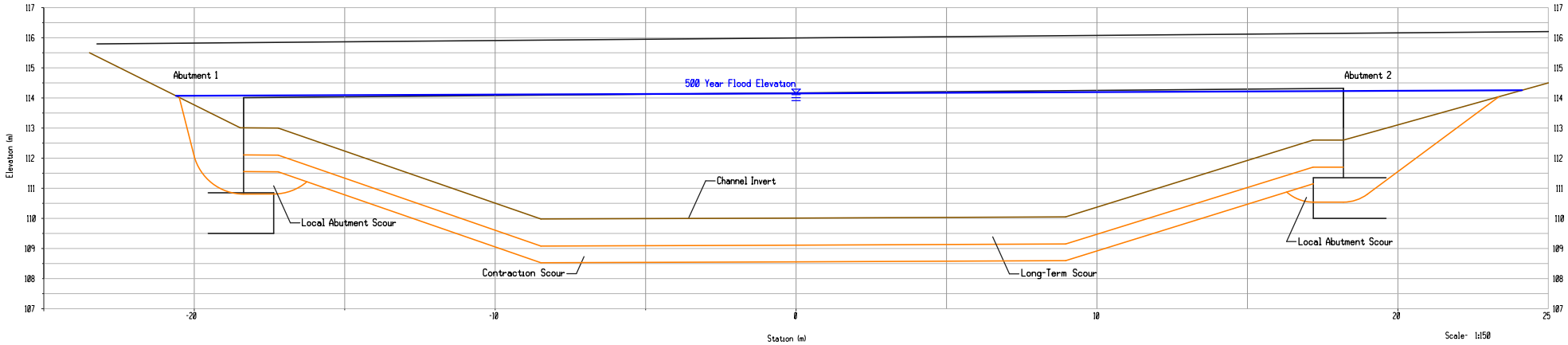
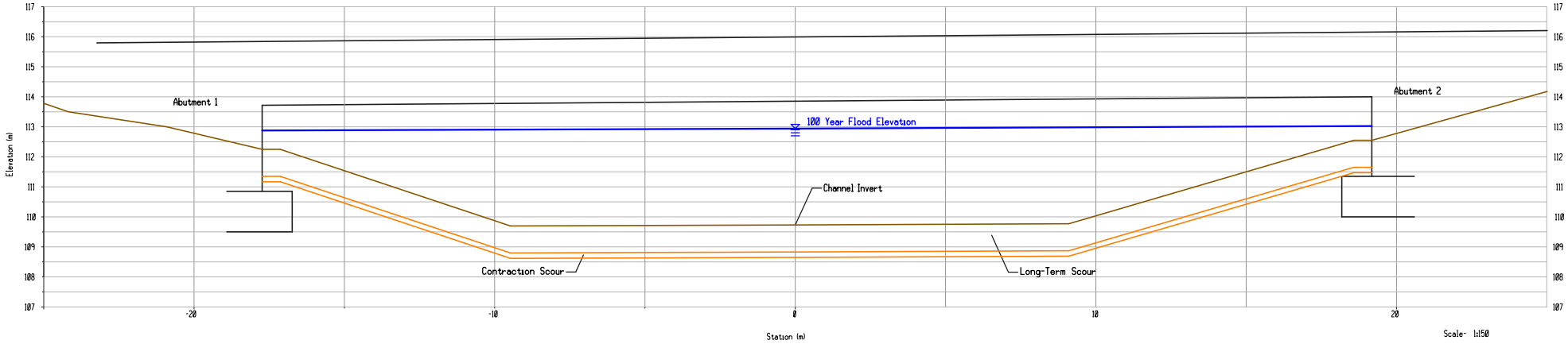


FIGURE 5A

Figure 5b. Scour Depth Cross Sections

Proposed I-84 Bridge No. 05774, Section Along The Downstream Face, I-84 Waterbury Project 151-273, Mad River



Proposed I-84 Bridge No. 05774, Section Along The Downstream Face, I-84 Waterbury Project 151-273, Mad River

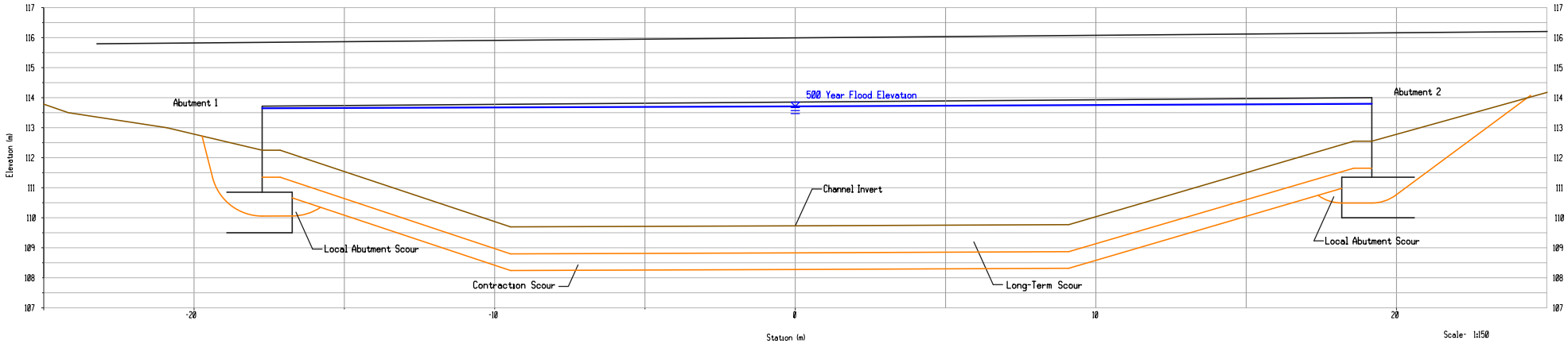
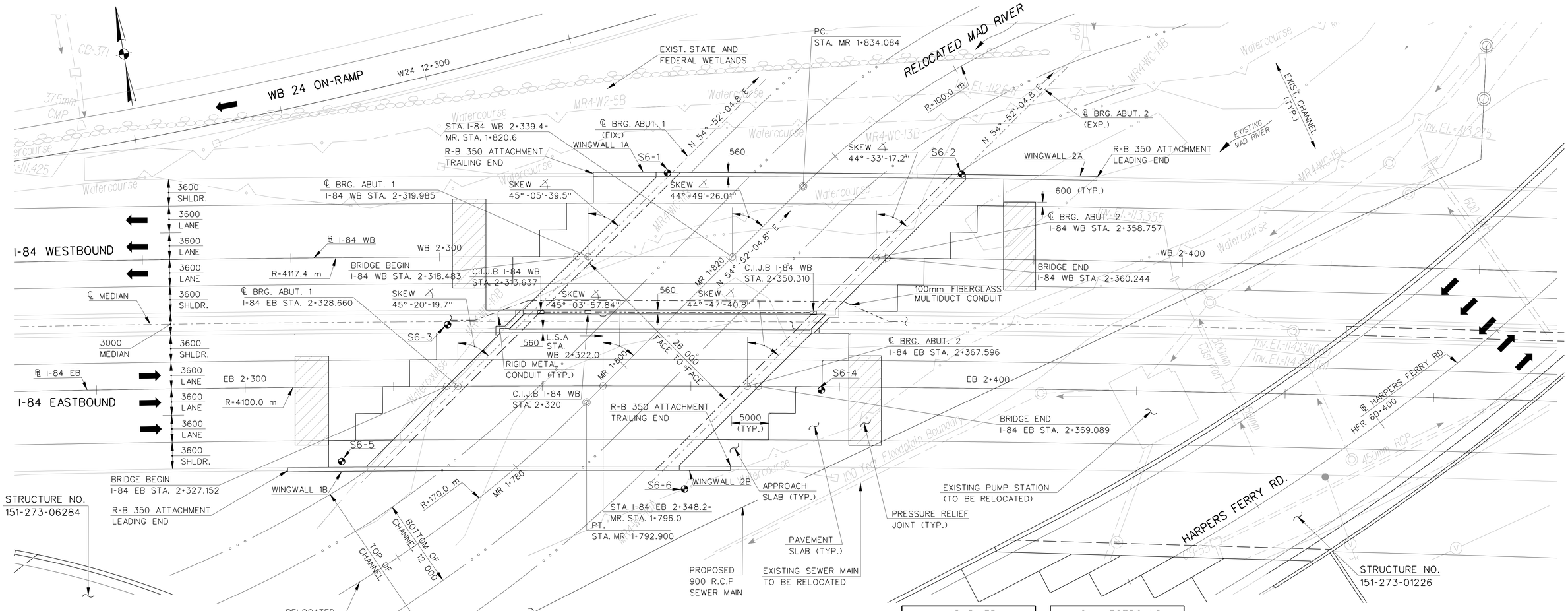


FIGURE 5B

Appendix A: Structure Plans & Details

(Note: The plans and details included in this report are intended for information purposes only. If there are any discrepancies to the actual construction or "as-built" plans, the information reflected on the construction or "as-built" plans shall be construed more accurate.)

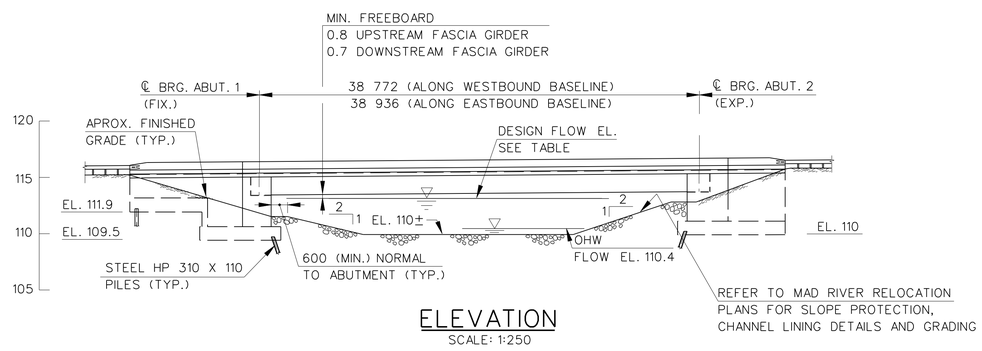


PLAN

SCALE: 1:250

BORING LEGEND

- BORING (2001)



ELEVATION

SCALE: 1:250

MAD RIVER	
P.C.	STA. 1+678.188
	N 230796.817
	E 282838.595
C.C.	N 230966.495
	E 282849.062
P.T.	STA. 1+792.900
	N 230827.464
	E 282946.891
Δ	38°-39'-42.75"
R	170.0 m
T	59.636 m
L	114.712 m

I-84 WESTBOUND	
P.C.	STA. 2+192.038
	N 230866.518
	E 282824.014
C.C.	N 226789.121
	E 282251.463
P.T.	STA. 2+753.408
	N 230750.859
	E 283372.895
Δ	7°-48'-42.30"
R	4117.4 m
T	281.120 m
L	561.370 m

MAD RIVER	
P.C.	STA. 1+834.084
	N 230851.164
	E 282980.572
C.C	N 230769.381
	E 283038.118
P.T.	STA. 1+882.517
	N 230868.552
	E 283025.269
Δ	27°-44'-59.37"
R	100.0 m
T	24.701 m
L	48.433 m

I-84 EASTBOUND	
P.C.	STA. 2+218.750
	N 230849.287
	E 282821.594
C.C.	N 226789.121
	E 282251.463
P.T.	STA. 2+777.747
	N 230734.117
	E 283368.156
Δ	7°-48'-42.30"
R	4100.0 m
T	279.932 m
L	558.997 m

CURVE DATA

BRIDGE DESIGN SAFETY FACTORS

BRIDGE	Design(LRFD)	Rating (LFR)		
VEHICLE	HL-93	MS 18	P204	P380
INVENTORY	1.58	1.57	-	-
OPERATING	2.05	2.62	1.12	1.43

BRIDGE/CULVERT NO.	05774
Drainage Area, km2	62.3
Design Frequency, year	100
Design Discharge, cms	176.98
Average Daily Flow Elevation, M	110.4 (observed)
Upstream Design Water Surface Elevation, M	113.24
Downstream Design Water Surface Elevation, M	112.94
Maximum Scour Elevation, M	110.49
Frequency (year)	500
Discharge (cms)	269.01
Worst case scour sub-strucutre unit	Abutment #2 (East)

REV.	DATE	DESCRIPTION	SHEET. NO.
		REVISIONS	

SCALE AS NOTED

DESIGNER: G. JIANG
DRAFTER: G. TOWNSEND
CHECKED BY: J. MUSKUS
DATE CHECKED: 12/2013

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

CADD ...\STR6\FD\0273f06001.brg
PLOTTED 5/21/2014

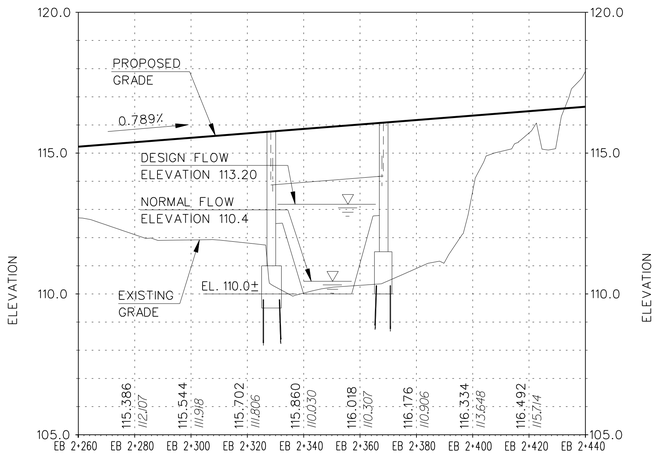
AMMANN & WHITNEY
2500 WESTCHESTER AVENUE
3RD FLOOR
HARRISON, NY

PROJECT TITLE:
RECONSTRUCTION OF I-84 WATERBURY
I-84 OVER MAD RIVER
STRUCTURE NO. 151-273-05774

TOWN: WATERBURY

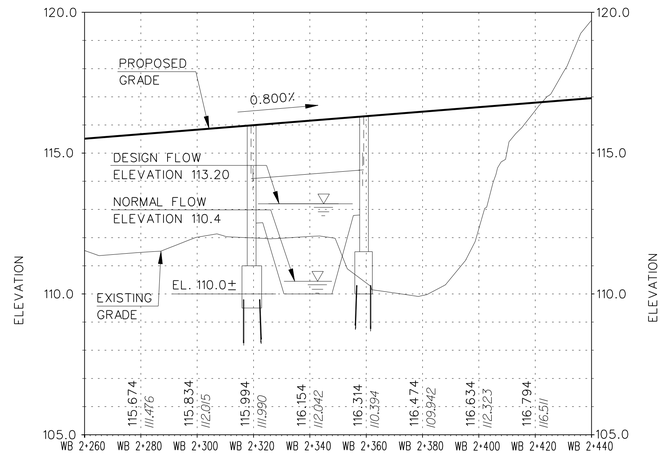
DRAWING TITLE: GENERAL PLAN AND ELEVATION

PROJECT NO.: 151-273
DRAWING NO.: S1
SHEET NO.: 05.05.001



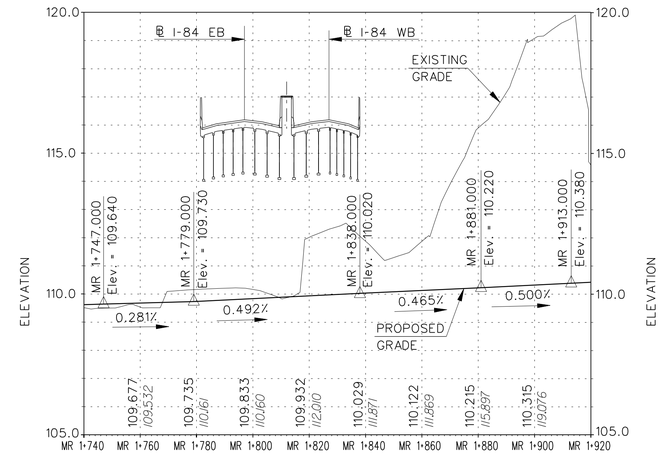
PROFILE EB I-84 OVER MAD RIVER

SCALE: HORIZ. 1:1000
VERT. 1:100



PROFILE WB I-84 OVER MAD RIVER

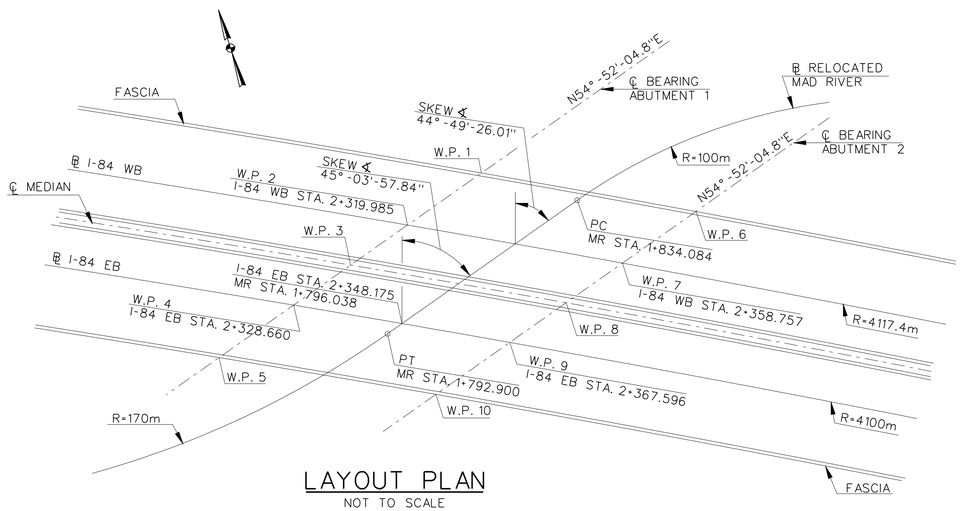
SCALE: HORIZ. 1:1000
VERT. 1:100



MAD RIVER PROFILE

SCALE: HORIZ. 1:1000
VERT. 1:100

WORKING POINT NO.	NORTH	EAST
W.P. 1	230856.0082	282963.5619
W.P. 2	230846.7606	282950.4196
W.P. 3	230839.6611	282940.3300
W.P. 4	230832.5462	282930.2186
W.P. 5	230823.2327	282916.9825
W.P. 6	230849.1608	283001.6179
W.P. 7	230839.9990	282988.5974
W.P. 8	230832.9659	282978.6021
W.P. 9	230825.9181	282968.5861
W.P. 10	230816.6934	282955.4762



LAYOUT PLAN

NOT TO SCALE

NOTES:

1. FOR CURVE DATA OF BASELINES, SEE GENERAL PLAN.

REV.	DATE	DESCRIPTION	SHEET. NO.

REVISIONS

SCALE AS NOTED

DESIGNER: G. JIANG
DRAFTER: G. TOWNSEND
CHECKED BY: J. MUSKUS
DATE CHECKED: 12/2013

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

CADD ...\str6\fd\0273f06004.brg
PLOTTED 4/4/2014

AMMANN & WHITNEY
2500 WESTCHESTER AVENUE
3RD FLOOR
HARRISON, NY

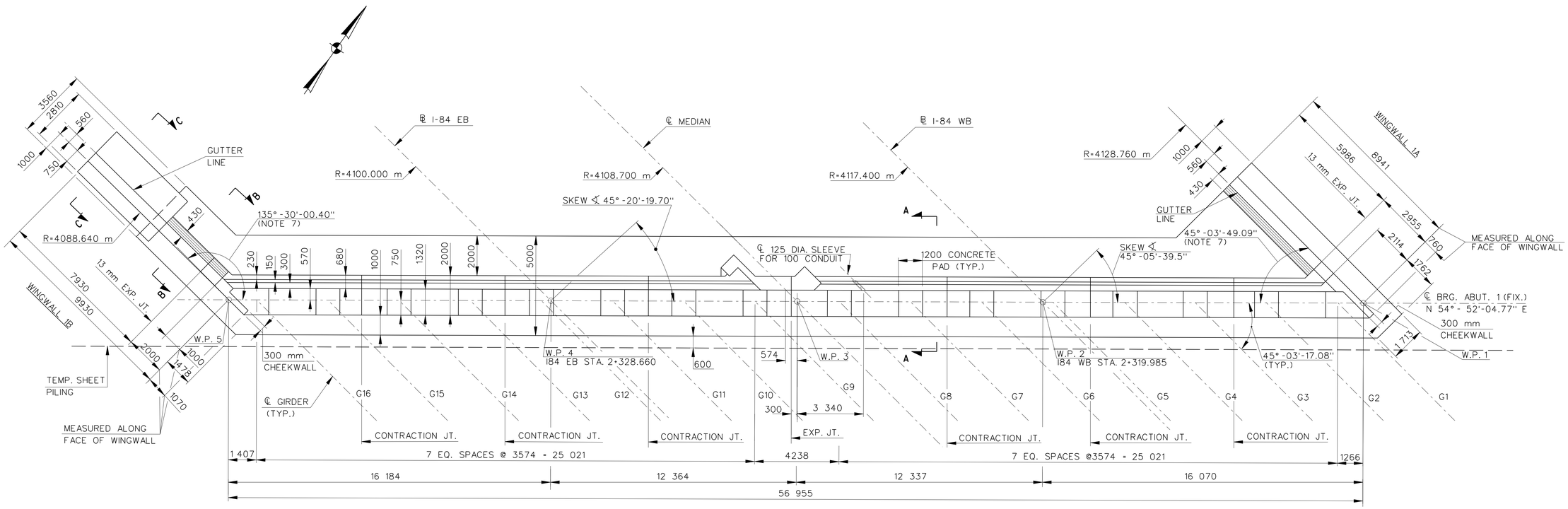
PROJECT TITLE:
RECONSTRUCTION OF I-84 WATERBURY
I-84 OVER MAD RIVER
STRUCTURE NO. 151-273-05774

TOWN: WATERBURY

DRAWING TITLE: PROFILES AND LAYOUT PLAN

PROJECT NO.: 151-273
DRAWING NO.: S4
SHEET NO.: 05.05.004

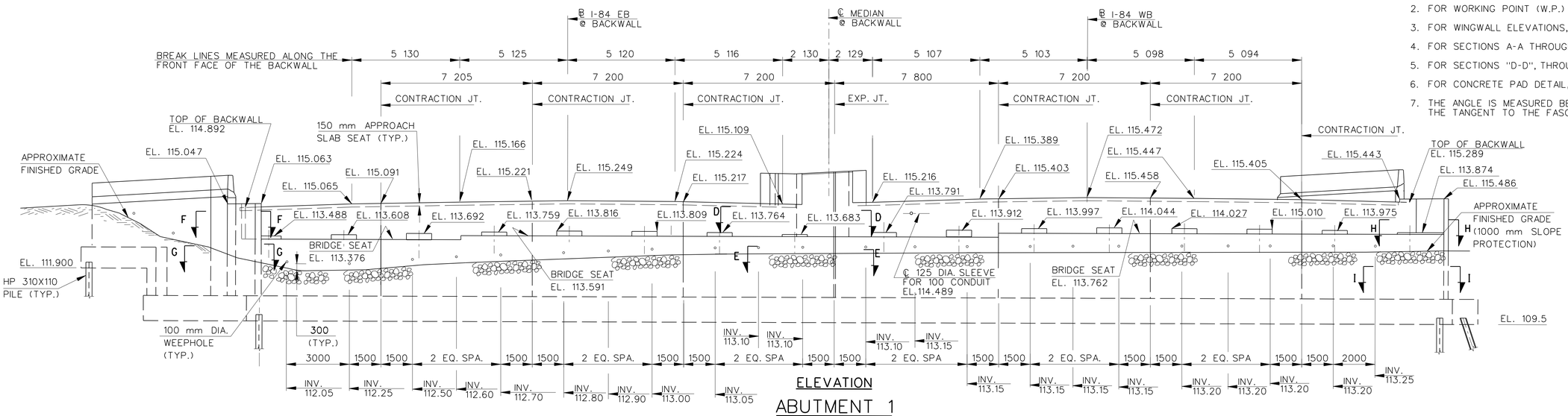
PROFILES



PLAN

NOTES

1. FOR PAY LIMITS OF TEMPORARY SHEET PILING, SEE STR. DWG. S17
2. FOR WORKING POINT (W.P.) COORDINATES, SEE STR. DWG. S4
3. FOR WINGWALL ELEVATIONS, SEE STR. DWG. S15
4. FOR SECTIONS A-A THROUGH C-C, SEE STR. DWG. S14
5. FOR SECTIONS "D-D", THROUGH I-I, SEE STR. DWG. S18
6. FOR CONCRETE PAD DETAIL, SEE STR. DWG. S16
7. THE ANGLE IS MEASURED BETWEEN C.L. OF BEARING AND THE TANGENT TO THE FASCIA AT THE WORKING POINT (W.P.)



ELEVATION

ABUTMENT 1

SCALE: 1:100

REV.	DATE	DESCRIPTION	SHEET. NO.
		REVISIONS	

SCALE AS NOTED

DESIGNER: G. JIANG
DRAFTER: G. TOWNSEND
CHECKED BY: J. MUSKUS
DATE CHECKED: 12/2013

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

CADD ...\str6\fd\0273f06012.brg
PLOTTED 4/2014

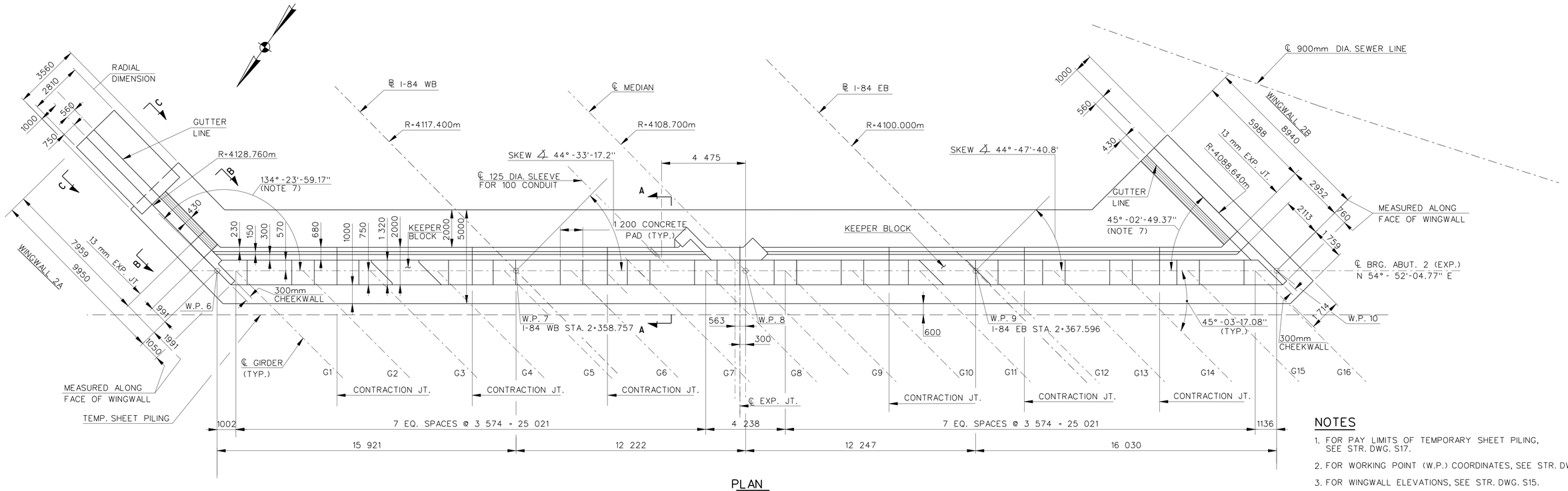
AMMANN & WHITNEY
2500 WESTCHESTER AVENUE
3RD FLOOR
HARRISON, NY

PROJECT TITLE:
RECONSTRUCTION OF I-84 WATERBURY
I-84 OVER MAD RIVER
STRUCTURE NO. 151-273-05774

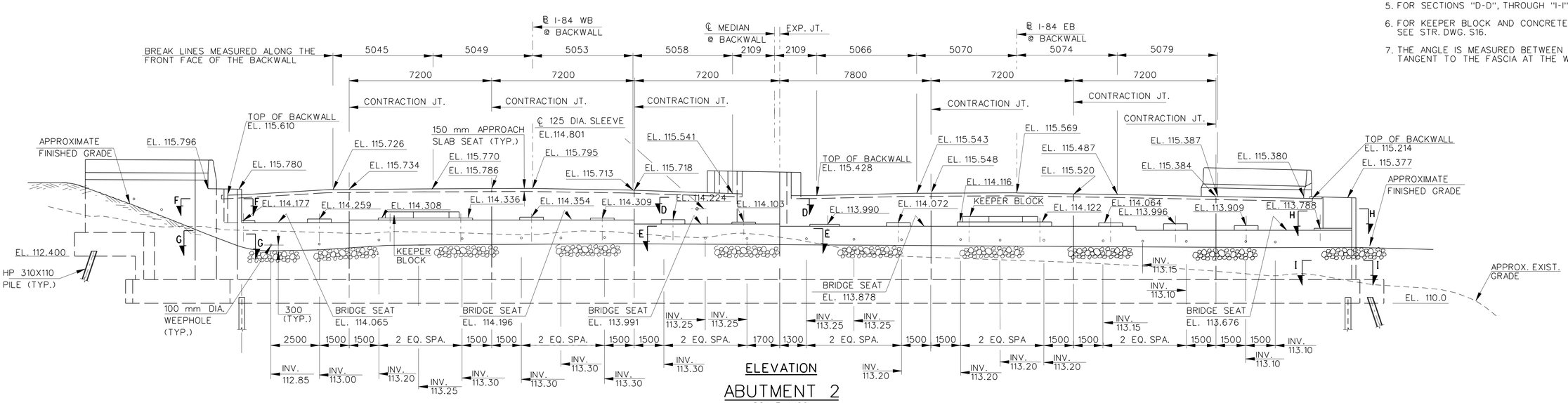
TOWN: WATERBURY

DRAWING TITLE: ABUTMENT 1 – PLAN AND ELEVATION

PROJECT NO.: 151-273
DRAWING NO.: S12
SHEET NO.: 05.05.012



PLAN



ELEVATION

ABUTMENT 2

SCALE: 1:100

NOTES

1. FOR PAY LIMITS OF TEMPORARY SHEET PILING, SEE STR. DWG. S17.
2. FOR WORKING POINT (W.P.) COORDINATES, SEE STR. DWG. S4.
3. FOR WINGWALL ELEVATIONS, SEE STR. DWG. S15.
4. FOR SECTIONS "A-A" THROUGH "C-C", SEE STR. DWG. S14.
5. FOR SECTIONS "D-D", THROUGH "I-I", SEE STR. DWG. S18.
6. FOR KEEPER BLOCK AND CONCRETE PAD DETAILS, SEE STR. DWG. S16.
7. THE ANGLE IS MEASURED BETWEEN C.L. OF BRGS. AND THE TANGENT TO THE FASCIA AT THE WORKING POINT (W.P.).

REV.	DATE	DESCRIPTION	SHEET. NO.
		REVISIONS	

SCALE AS NOTED

DESIGNER: G. JIANG
DRAFTER: G. TOWNSEND
CHECKED BY: J. MUSKUS
DATE CHECKED: 12/2013

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

CADD ...\str6\fd\0273f06014.brg
PLOTTED 4/1/2014

AMMANN & WHITNEY
2500 WESTCHESTER AVENUE
3RD FLOOR
HARRISON, NY

PROJECT TITLE: RECONSTRUCTION OF I-84 WATERBURY
I-84 OVER MAD RIVER
STRUCTURE NO. 151-273-05774

TOWN: WATERBURY

DRAWING TITLE: ABUTMENT 2 – PLAN AND ELEVATION

PROJECT NO.: 151-273
DRAWING NO.: S13
SHEET NO.: 05.05.013

Appendix B: Scour Computations

Based on DOT Design Discharges

- Summary Sheet
- 100-YR Contraction Scour
- 100-YR Abutment Scour
- 500-YR Contraction Scour
- 500-YR Abutment Scour

Final Design

Bridge No. 05774
Easterly I-84 Crossing over the Mad River
Computed Scour Depths using Froehlich's Abutment Scour Equation
July 2006 - Revised March 2014

Abutment #1- Westerly Abutment or Left Abutment Looking Upstream

Flood Recurrence	Ave. Flow Depth Obstructed	Scour Depth (m)				
		Long-Term	Contraction	Abutment Equation	Amended Abutment	Amended Total
Q_{100}	0.00	0.9	0.18	N/A	0.00	1.08
Q_{500}	0.49	0.9	0.554	Froehlich	0.734	2.19
Overtopping	> Q_{500}					

Abutment #2- Easterly Abutment or Right Abutment Looking Upstream

Flood Recurrence	Ave. Flow Depth Obstructed	Scour Depth (m)				
		Long-Term	Contraction	Abutment Equation	Amended Abutment	Amended Total
Q_{100}	0.00	0.9	0.18	N/A	0.00	1.08
Q_{500}	0.45	0.9	0.554	Froehlich	0.604	2.06
Overtopping	> Q_{500}					

Comparison of Footing Elevations to Computed Scour Depths

Abutment No.	Depth of Footing (m)	Elevation (m)		Assumed Ground Elevation at Base of Abutment	Elevation of Scour at Abutment (m)			
					100 Year Discharge		500 Year Discharge	
		Top of Footing	Bottom of Footing		Long-Term + Contraction	Total	Long-Term + Contraction	Total
1	1.35	110.85	109.5	112.25 *	111.17	111.17	110.80	110.06
2	1.35	111.35	110.0	112.55	111.47	111.47	111.10	110.49

** The lowest elevation is 111.8 M (112.05-0.3+(0.1/2)) near the downstream end. However, as it is located inside of a curve where the flow begins to shift/elevate toward the other abutment, it is not the best representative of the ground elevation for the scour assessment. Thus, use the next reasonable, low ground elevationis which is 112.25 M. More than 90% of the ground adjacent to the abument is above this elevation.*

Abutment No. 1

-Top of footing below the sum of long-term channel degradation and contraction scour depths for the 100 year discharge- Design OK

-Computed total scour depth for the 100 year discharge is above the bottom of the footing, piles are not exposed by scour

-Computed total scour depth for the 500 year discharge is above the bottom of the footing, piles are not exposed by scour

Abutment No. 2

-Top of footing below the sum of long-term channel degradation and contraction scour depths for the 100 year discharge- Design OK

-Computed total scour depth for the 100 year discharge is above the bottom of the footing, piles are not exposed by scour

-Computed total scour depth for the 500 year discharge is above the bottom of the footing, piles are not exposed by scour
Although the scour depth is less than that for Abutment No. 1, this is considered to be the worst case, as it causes a larger portion of the footing to be exposed.

PROJECT NO. 151-273 **BRIDGE NO.** 05774 **UNIT:** Metric

Ref. HEC-18., May 2001 (4th ed.)

SUMMARY

Contraction Scour		Type:	**LIVE-BED**	Depth:	**0.18** m	Event:	**100-YR**
Local	**West Abut. #1**	**LEFT**	Eq.: N/A	Depth:	**N/A** m	Event:	**100-YR**
Abutment	**East Abut. #2**	**RIGHT**	Eq.: N/A	Depth:	**N/A** m	Event:	**100-YR**

CONTRACTION SCOUR

$Vc = Ku\ y^{1/6}\ D^{1/3}$ .....Eq. 5.1

= **0.51** ***m/s*** Critacal velocity above which bed material of size D and smaller will be transported

Ku = 6.19 m (6.19 in SI units; 11.17 in English units)

y = 2.84 m Average depth of flow upstream of the bridge

D = 0.00034 m Particle size for Vc , *m* (use D_{50})

V1 = **3.02** ***m/s*** The mean velocity of the flow in the main channel or overbank area upstream of the brige opening

Vc < V1 ***Thus, LIVE-BED CONTRACTION SCOUR***

Live-Bed Contraction Scour ==========

$Y_2/Y_1 = (Q_2/Q_1)^{6/7}\ (W_1/W_2)^{k_1}$ = **1.01** .....Eq. 5.2

$Y_s = Y_2 - Y_o$ **m** .....Eq. 5.3

= **0.18 m** Average contraction scour depth

Y_1 = 2.84 m Average depth in the upstream main channel

Y_2 = 2.88 m Average depth in the contracted section

Y_o = 2.70 m Existing depth in the contracted section before scour

Q_1 = 172.72 m3/s Flow in the upstream channel transporting sediment

Q_2 = 175.52 m3/s Flow in the contracted channel

W_1 = 12.00 m Bottom width of the upstream main channel that is transporting bed material

W_2 = 12.00 m Bottom width of the main channel in the contracted section less pier width

k_1 = 0.69 Exponent determined below (V^*/ω = 6.46)

V^* = 0.3232 $=(T_o/\rho)^{1/2}$ or $(gY1\ S1)^{1/2}$, shear velocity in the upstream section , m/s

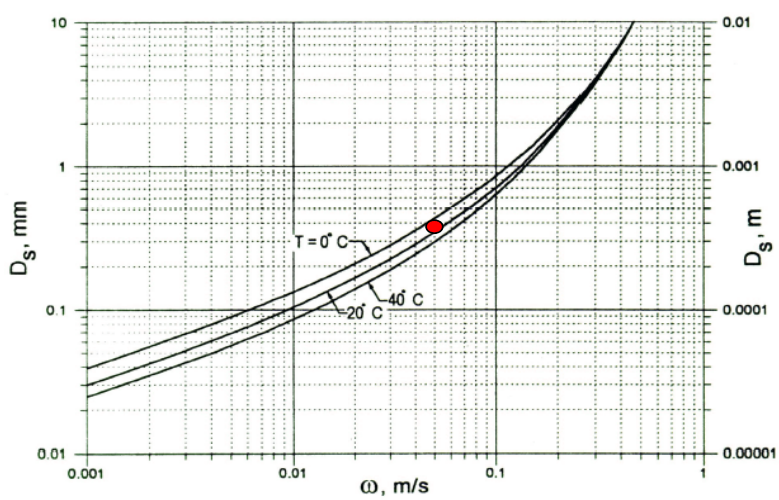
ω = 0.05 m/s Fall velocity of bed material based on the D_{50} (Figure 5.8)

g = 9.81 m/s^2 Acceleration of gravity

S1 = 0.002742 m/m Slope of energy gradeline of main channel

T_o = 104.45 Pa (N/m^2) Shear stess on the bed

ρ = 1000 kg/m^3 Density of water



V/ω*	*k1*	*Mode of Bed Material Transport*
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

Figure 5.8. Fall velocity of sand-sized particles with specific gravity of 2.65 in metric units.

Clear-Water Contraction Scour ==========

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2}\right]^{3/7}$$ .....Eq. 5.4

$$y_s = y_2 - y_o$$ **m** .....Eq. 5.5

=	**N/A**	**m**	Average contraction scour depth **LIVE-BED controls. Ignore this procedure**
y_2 =	18.99	m	Average equilibrium depth in the contracted section after contraction scour
y_o =	2.70	m	Average existing depth in the contracted section
Q =	176.98	m3/s	Discharge through the bridge or on the set-back overbank area at the bridge associated with the width W
W =	12.00	m	Bottom width of the contracted section less pier widths
K_u =	0.0250		(0.025 in SI units; 0.0077 in English units)
D_m =	0.0004	m	Diameter of the smallest nontransportable particle in the bed material (1.25 D_{50}) in th contacted setion
D_{50} =	0.0003	m	Median diameter of bed material

Because D_{50} is not the largest particle in the bed material, the scoured section can be slightly armored. Therefore, the D_m is assumed to be 1.25 D_{50}. For stratified bed material the depth of scour can be determined by using the clear-water scour equation sequentially with successive D_m of the bed material layers.

Data Source

			From:	RS
Eq. 5.1				
y =	2.84	m	D	1900
V1 =	3.02	m	D	1807.5 BR U
Eq. 5.2 & 5.3				
Y1 =	2.84	m	D	1900
Yo =	2.70	m	D	1807.5 BR U
Q1 =	172.72	m3/s	D	1900
Q2 =	175.52	m3/s	D	1807.5 BR U
W1 =	enter bottom	m	M	1900
or	12	m (manual)		
W2 =	enter bottom	m	M	1807.5 BR U
or	12	m (manual)		
S1 =	0.002742	m/m	C	1900
To =	104.45	Pa (N/m^2)	C	1807.5 BR U
P2 =	0	m (pier width)		
Eq. 5.4 & 5.5				
Q =	176.98	m3/s	C	1807.5

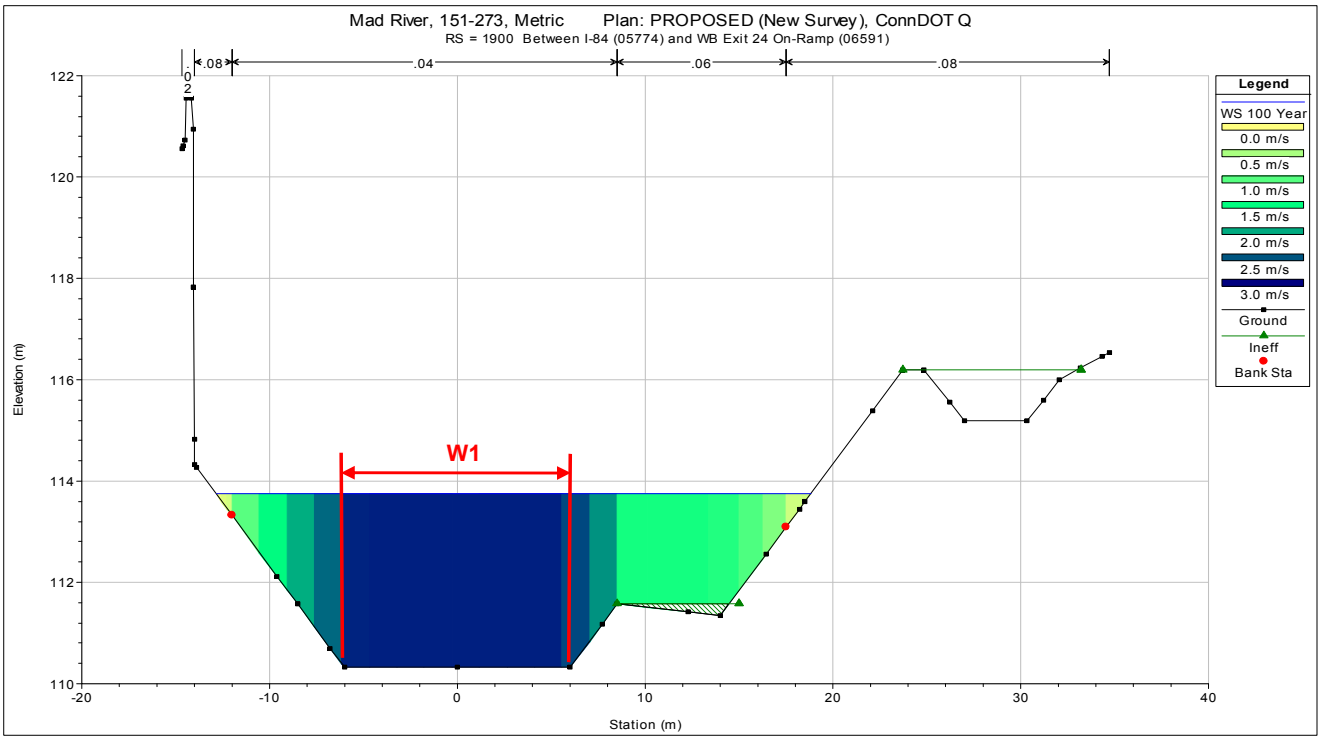
From Flow Distribution Columns where V > 1 m/s

Legends:

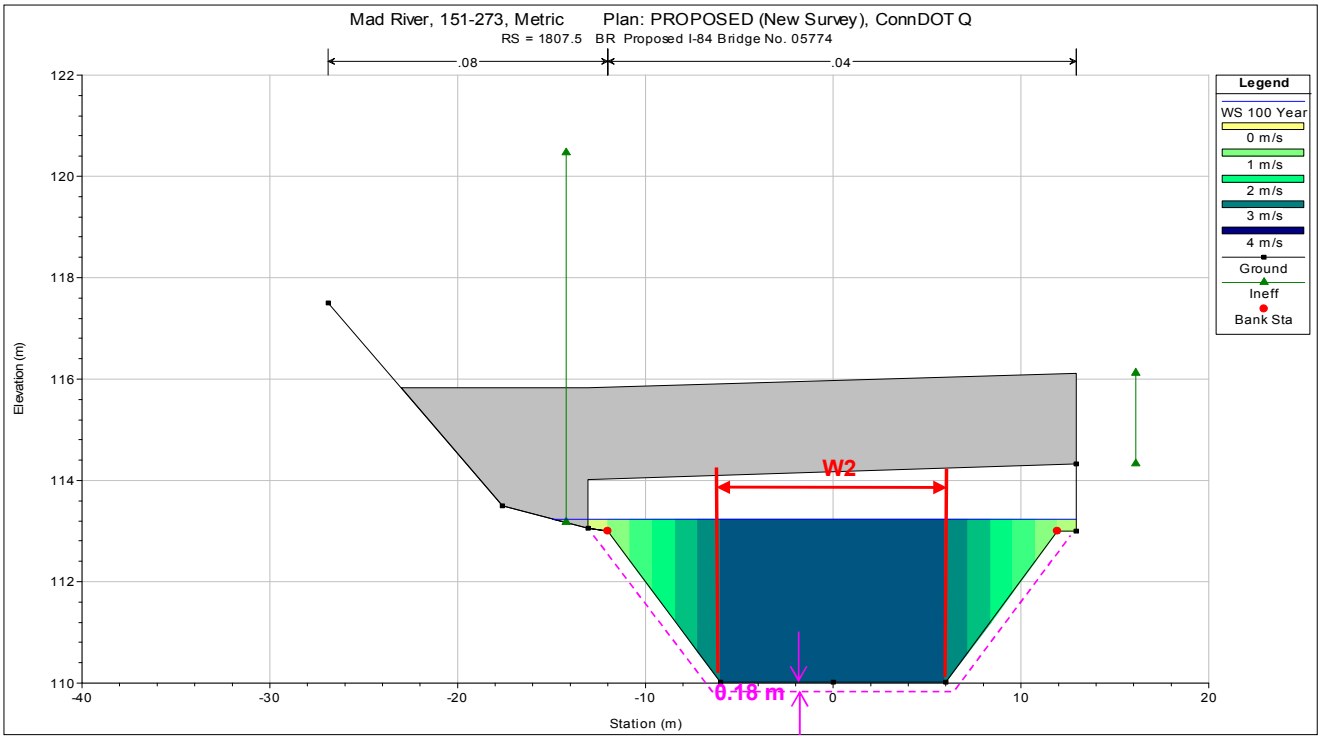
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections used for Constraction Scour Computations

UPSTREAM SECTION 1900



CONTRACTED SECTION 1807.5 BR U



UPSTREAM CHANNEL SECTION

River Station 1900 Event: 100-YR

HEC-RAS CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1900 Profile: 100 Year

			Left OB	Channel	Right OB	Total
E.G. Elev (m)	114.01	Element				
Vel Head (m)	0.27	Wt. n-Val.	0.08	0.043	0.08	
W.S. Elev (m)	113.74	Reach Len. (m)	29.4	29.4	29.4	
Crit W.S. (m)		Flow Area (m2)	0.18	76.96	0.42	
E.G. Slope (m/m)	0.002742	Area (m2)	0.18	77.61	0.42	78.21
Q Total (m3/s)	176.98	Flow (m3/s)	0.04	176.82	0.12	
Top Width (m)	31.67	Top Width (m)	0.85	29.53	1.29	
Vel Total (m/s)	2.28	Avg. Vel. (m/s)	0.22	2.3	0.29	
Max Chl Dpth (m)	3.42	Hydr. Depth (m)	0.21	2.61	0.33	2.47
Conv. Total (m3/s)	3379.7	Conv. (m3/s)	0.7	3376.7	2.3	
Length Wtd. (m)	29.4	Wetted Per. (m)	0.95	30.95	1.44	
Min Ch El (m)	110.32	Shear (N/m2)	5.1	66.86	7.84	
Alpha	1.01	Stream Power (N/m s)	1661.36	0	0	
Frctn Loss (m)	0.11	Cum Volume (1000 m3)	9.82	63.76	4.23	
C & E Loss (m)	0.05	Cum SA (1000 m2)	23.48	27.11	6.49	

	Flow dis.	*manual*
Left WS Sta.	-13.06	-12.86
Left Convy Sta.	-12.54	
Left Main Channel	-10.55	-6
Right Main Channel	15	6
Right Convy Sta.	16.26	
Right WS Sta.	19.07	18.81
L' (left) 1.99	L (left)	2.31
L' (Right) 1.26	L (Right)	3.81

HEC-RAS FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		1.17	1.34		
Main	25.55	172.72	72.6	2.84	2.38
Right		3.11	3.63		

Plan: PR_DOT Mad River Reach 1 RS: 1900 Profile: 100 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	LOB	-13.06	-12.8	0	0	0.07	0	0.01	0.03	0.36	0.01
2	LOB	-12.8	-12.54	0	0.03	0.29	0	0.1	0.11	2.3	0.25
3	LOB	-12.54	-12.27	0.01	0.06	0.29	0.01	0.23	0.19	5.46	1.05
4	LOB	-12.27	-12.01	0.02	0.09	0.29	0.01	0.36	0.26	8.63	2.26
5	Chan	-12.01	-10.55	1.14	1.16	1.64	0.65	0.79	0.98	19.04	18.74
6	Chan	-10.55	-9.08	3.41	2.24	1.64	1.93	1.53	1.53	36.73	56.04
7	Chan	-9.08	-7.62	6.53	3.3	1.64	3.69	2.25	1.98	54.25	107.34
8	Chan	-7.62	-6.15	10.44	4.38	1.64	5.9	2.99	2.39	71.86	171.5
9	Chan	-6.15	-4.69	13.99	5.01	1.48	7.9	3.42	2.79	90.91	253.78
10	Chan	-4.69	-3.22	14.13	5.02	1.46	7.98	3.42	2.82	92.09	259.27
11	Chan	-3.22	-1.76	14.13	5.02	1.47	7.98	3.42	2.82	92.09	259.27
12	Chan	-1.76	-0.29	14.13	5.02	1.46	7.98	3.42	2.82	92.09	259.27
13	Chan	-0.29	1.17	14.13	5.02	1.46	7.98	3.42	2.82	92.09	259.27
14	Chan	1.17	2.64	14.13	5.02	1.47	7.98	3.42	2.82	92.09	259.27
15	Chan	2.64	4.1	14.13	5.02	1.46	7.98	3.42	2.82	92.09	259.27
16	Chan	4.1	5.57	14.13	5.02	1.46	7.98	3.42	2.82	92.09	259.27
17	Chan	5.57	7.03	12.23	4.75	1.59	6.91	3.24	2.58	80.55	207.44
18	Chan	7.03	8.5	7.99	3.73	1.64	4.51	2.54	2.14	61.14	130.99
19	Chan	8.5	10.13	4.9	3.53	1.63	2.77	2.17	1.39	58.43	80.98
20	Chan	10.13	11.75	4.9	3.53	1.63	2.77	2.17	1.39	58.43	80.98
21	Chan	11.75	13.38	4.9	3.53	1.63	2.77	2.17	1.39	58.43	80.98
22	Chan	13.38	15	4.52	3.46	1.74	2.55	2.13	1.31	53.45	69.8
23	Chan	15	16.26	2.09	2	1.41	1.18	1.59	1.04	38.23	39.93
24	Chan	16.26	17.52	0.9	1.21	1.41	0.51	0.96	0.75	23.08	17.22
25	ROB	17.52	19.07	0.12	0.42	1.44	0.07	0.33	0.29	7.84	2.26
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CONTRACTED CHANNEL SECTION

River Station 1807.5 BR U

CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1807.5 BR U Profile: 100 Year

			Left OB	Channel	Right OB	Total
E.G. Elev (m)	113.69	Element				
Vel Head (m)	0.45	Wt. n-Val.	0.08	0.04	0.04	
W.S. Elev (m)	113.24	Reach Len. (m)	58.8	58.8	58.8	
Crit W.S. (m)	112.44	Flow Area (m2)	0.22	59.45	0.24	
E.G. Slope (m/m)	0.004547	Area (m2)	0.22	59.45	0.24	59.91
Q Total (m3/s)	176.98	Flow (m3/s)	0.07	176.78	0.13	
Top Width (m)	26.01	Top Width (m)	1.03	23.97	1.01	
Vel Total (m/s)	2.95	Avg. Vel. (m/s)	0.3	2.97	0.56	
Max Chl Dpth (m)	3.23	Hydr. Depth (m)	0.21	2.48	0.24	2.30
Conv. Total (m3/s)	2624.6	Conv. (m3/s)	1	2621.6	2	
Length Wtd. (m)	58.8	Wetted Per. (m)	1.03	25.38	1.25	
Min Ch El (m)	110.01	Shear (N/m2)	9.44	104.45	8.55	
Alpha	1.01	Stream Power (N/m s)	620.97	0	0	
Frctn Loss (m)	0.29	Cum Volume (1000 m3)	9.81	59.68	4.22	
C & E Loss (m)	0	Cum SA (1000 m2)	23.45	25.47	6.45	

	Flow dis.	*manual*
Left WS Sta.	-14.2	-14.93
Left Flood Sta.		-13.04
Left Main Channel	-10.81	-6
Right Main Channel	10.76	6
Right Flood Sta.		12.87
Right WS Sta.	12.97	12.97

L' (left)	2.23	L (left)	4.12
L' (Right)	2.11	L (Right)	2.21

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		0.67	0.86		
Main	21.57	175.52	58.21	2.70	3.02
Right		0.7	0.84		

Plan: PR_DOT Mad River Reach 1 RS: 1807.5 BR U Profile: 100 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	LOB	-14.2	-12.01	0.07	0.22	1.03	0.04	0.21	0.3	9.44	2.82
2	Chan	-12.01	-10.81	0.6	0.64	1.34	0.34	0.53	0.93	21.36	19.92
3	Chan	-10.81	-9.61	2.08	1.36	1.34	1.18	1.13	1.54	45.16	69.38
4	Chan	-9.61	-8.41	4.22	2.07	1.34	2.38	1.73	2.04	68.97	140.5
5	Chan	-8.41	-7.22	6.91	2.79	1.34	3.91	2.32	2.48	92.77	230.31
6	Chan	-7.22	-6.02	10.12	3.5	1.34	5.72	2.92	2.89	116.58	337.01
7	Chan	-6.02	-4.82	12.85	3.87	1.2	7.26	3.23	3.32	143.64	477.26
8	Chan	-4.82	-3.62	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
9	Chan	-3.62	-2.42	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
10	Chan	-2.42	-1.22	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
11	Chan	-1.22	-0.02	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
12	Chan	-0.02	1.17	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
13	Chan	1.17	2.37	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
14	Chan	2.37	3.57	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
15	Chan	3.57	4.77	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
16	Chan	4.77	5.97	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
17	Chan	5.97	7.17	10.25	3.53	1.34	5.79	2.94	2.91	117.61	341.99
18	Chan	7.17	8.36	6.99	2.81	1.34	3.95	2.34	2.49	93.31	232.56
19	Chan	8.36	9.56	4.26	2.09	1.34	2.41	1.74	2.04	69.35	141.81
20	Chan	9.56	10.76	2.1	1.36	1.34	1.19	1.14	1.54	45.39	69.96
21	Chan	10.76	11.96	0.6	0.64	1.34	0.34	0.54	0.93	21.42	20.02
22	ROB	11.96	12.06	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
23	ROB	12.06	12.16	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
24	ROB	12.16	12.26	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
25	ROB	12.26	12.36	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
26	ROB	12.36	12.46	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
27	ROB	12.46	12.57	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
28	ROB	12.57	12.67	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
29	ROB	12.67	12.77	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
30	ROB	12.77	12.87	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
31	ROB	12.87	12.97	0.01	0.02	0.34	0	0.24	0.27	3.16	0.84
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LIVE SCOUR AT ABUTMENTS

Froehlich's Live-Bed Abutment Scour Equation — *LEFT* — *RIGHT* — ==========

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 1 =$ — **N/A** — **N/A** — .....Eq. 7.1

Amended Local Scour Equation

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 0.05 =$ — **N/A** — **N/A** — .....CT DOT DM Pg 9B-2

	LEFT	RIGHT		
Ys =	**N/A**	**N/A**	**m**	Scour depth <== using Amended equation
K_1 =	1.00	1.00		Coeffcient for abutment shape (see Table 7.1 and Figrue 7.6)
K_2 =	1.05	0.91		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
θ =	135	45		
				θ < 90 degrees if embankment points downstream
				θ > 90 degrees if embankment points upstream
				(see Figure 7.5 for definition of θ)
L' =	0.00	0.00	m	Length of active flow obstructed by the embankment (see Figure 7.4)
Ae =	0.00	0.00	m^2	Flow area of the approach cross section obstructed by the embankment
Fr =	N/A	N/A		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment
Ve =	N/A	N/A	m/s	Qe/Ae
Qe =	0	0	m^3/s	Flow obstructed by the abutment and approach embankment
Ya =	N/A	N/A	m	Ae/L, Average depth of flow on the floodplain
L =	0	0	m	Length of embankment projected normal to the flow

Table 7.1. Abutment Shape Coefficients.

Description	K_1
Vertical-wall abutment	1.00
Vertical-wall abutment with wing walls	0.82
Spill-through abutment	0.55

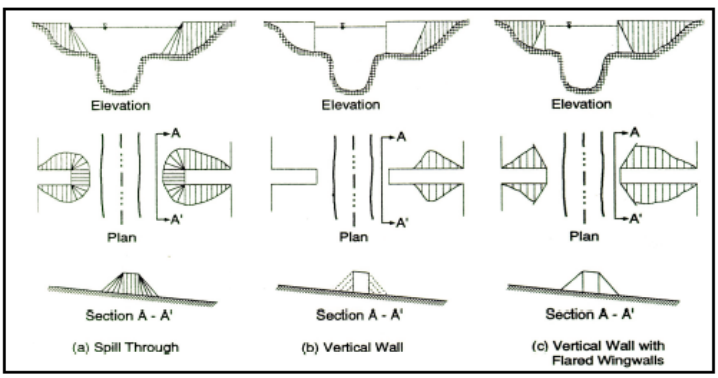


Figure 7.6. Abutment shape.

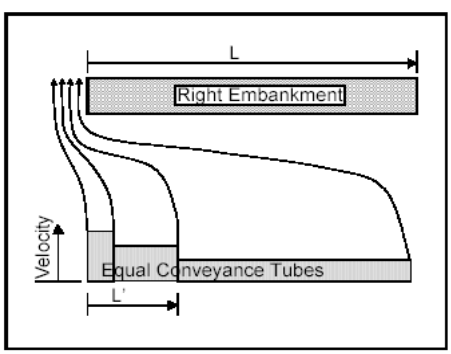


Figure 7.4. Determination of length of embankment blocking live flow for abutment scour estimation.

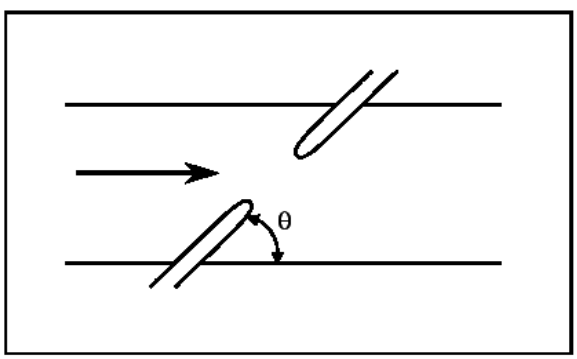


Figure 7.5. Orientation of embankment angle, θ, to the flow.

HIRE Live-Bed Abutment Scour Equation ==========

		LEFT	RIGHT	
Applicability check:	L/Y_1 =	N/A	N/A	*Use HIRE Eq. only if $L/Y_1 > 25$*
$Y_s/Y_1 = 4\ Fr^{0.33}\ K_1/0.55\ K_2$ =		**N/A**	**N/A**	.....Eq. 7.1

	LEFT	RIGHT		
Y_s =	**N/A**	**N/A**	**m**	Scour depth (N/A if $L/Y_1 < 25$)
K_1 =	1.00	1.00		Coeffcient for abutment shape (see Table 7.1 on RIGHT)
K_2 =	1.05	0.91		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
Y_1 =	N/A	N/A	m	Depth of flow at the abutment on the overbank or in the main channel,
Fr =	N/A	N/A		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment

Data Source

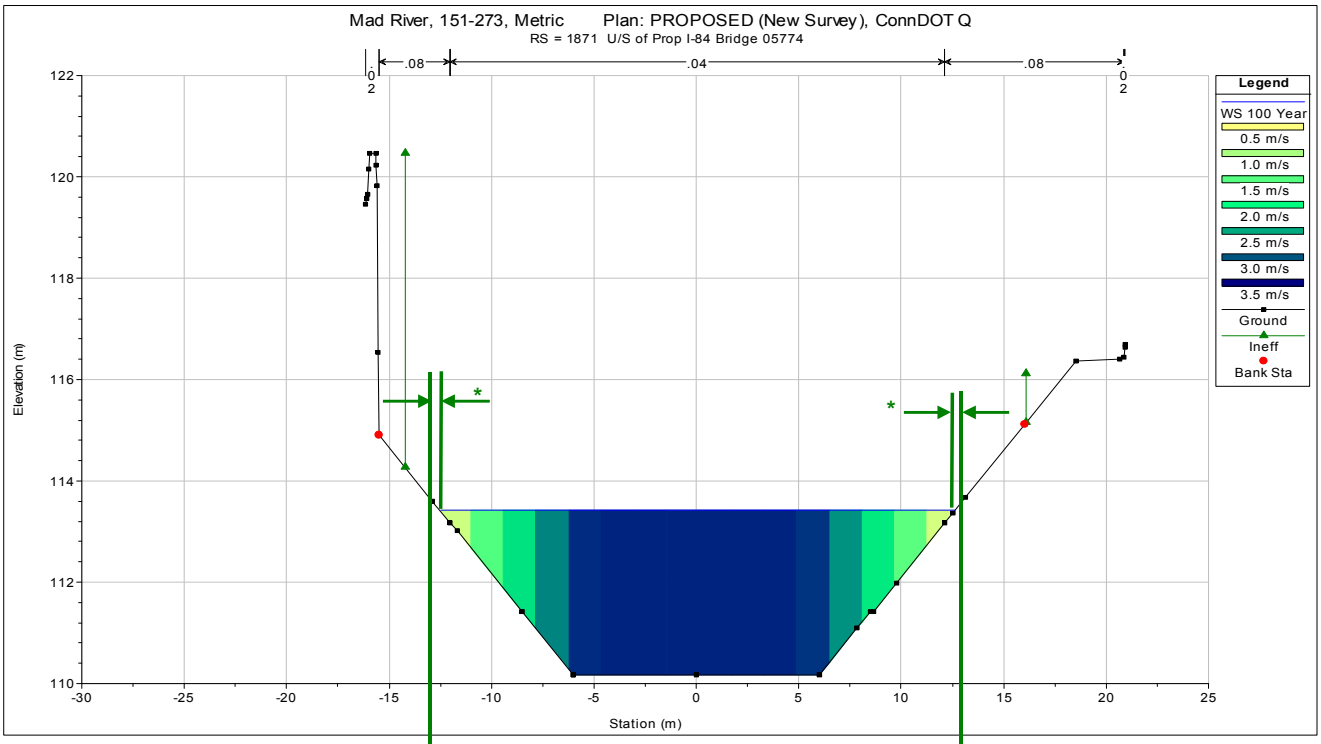
Eq. 7.1			From:	RS
LT			UC	
	L' =	0 m	D	1871
	Ae =	0 m2	D	1871
	Qe =	0 m3/s	D	1871
	L =	0 m	D	1871
RT			UC	
	L' =	0 m	D	1871
	Ae =	0 m2	D	1871
	Qe =	0 m3/s	D	1871
	L =	0 m	D	1871

Legends:

UC	from an upstream Cross Section output (approach section)
UF	from Bridge Upstream Face - Cross Section output (BR U); or Bridge Downstream Face (BR D) - this is seldom used
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

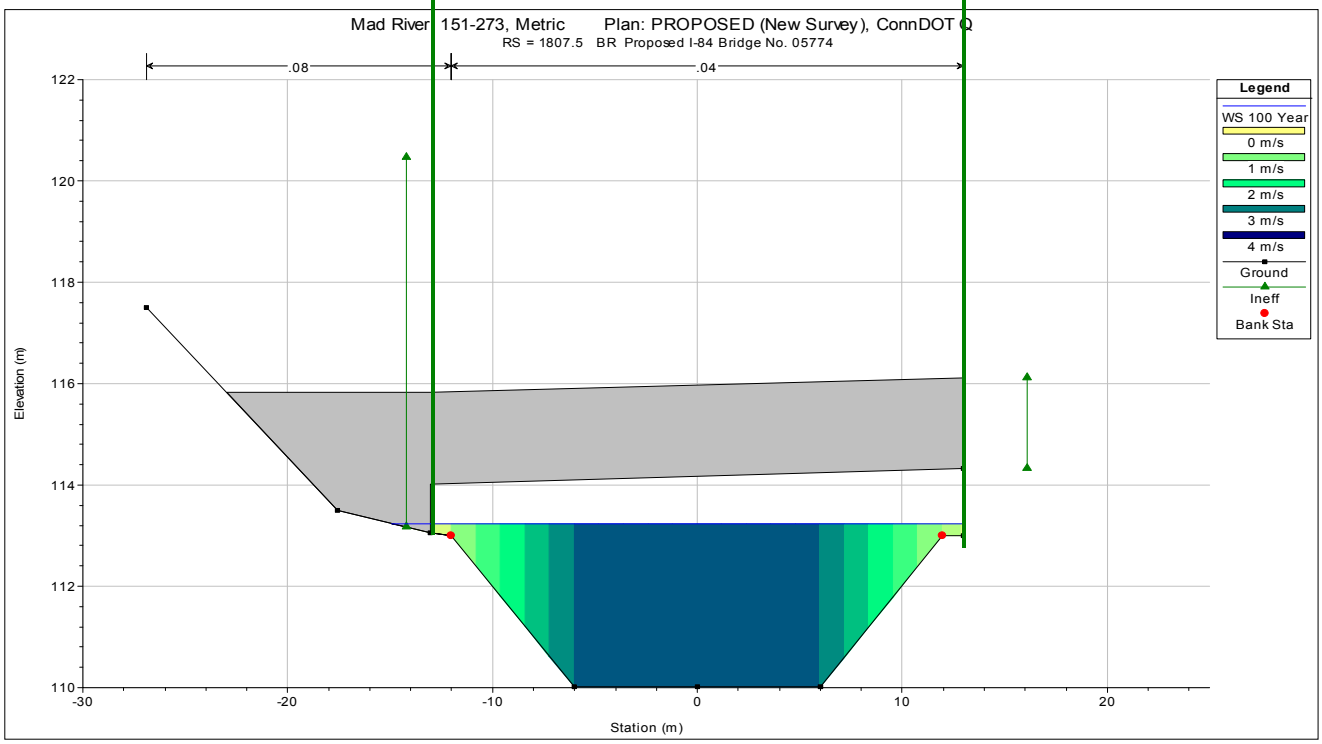
Cross Sections Used for Local Abutment Scour Computations

APPROACH SECTION 1871



* Although the 100-year flood comes in contact with the abutments, the effective length of obstructed flow is zero, as the flow width at the upstrem section is narrower. Thus, the local abutment scour flow is not likely to occur.

BRIDGE SECTION 1807.5 BR U



UPSTREAM APPROACH CHANNEL SECTION

River Station 1871 | Event: 100-YR

CROSS SECTION OUTPUT ***Use the same data as in the contraction scour computation?*** No

Plan: PR_DOT Mad River Reach 1 RS: 1871 Profile: 100 Year

E.G. Elev (m)	113.85	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.44	Wt. n-Val.		0.042		
W.S. Elev (m)	113.42	Reach Len. (m)	34.24	34.24	34.24	
Crit W.S. (m)	112.6	Flow Area (m2)		60.31		
E.G. Slope (m/m)	0.005118	Area (m2)		60.31		60.31
Q Total (m3/s)	176.98	Flow (m3/s)		176.98		
Top Width (m)	25.14	Top Width (m)		25.14		
Vel Total (m/s)	2.93	Avg. Vel. (m/s)		2.93		
Max Chl Dpth (m)	3.25	Hydr. Depth (m)		2.4		2.40
Conv. Total (m3/s)	2473.8	Conv. (m3/s)		2473.8		
Length Wtd. (m)	34.24	Wetted Per. (m)		26.67		
Min Ch El (m)	110.17	Shear (N/m2)		113.48		
Alpha	1	Stream Power (N/m s)	1002.08	0	0	
Frctn Loss (m)	0.17	Cum Volume (1000 m3)	9.81	61.73	4.22	
C & E Loss (m)	0	Cum SA (1000 m2)	23.47	26.31	6.47	

	Flow dis.	*manual*
Left WS Sta.	-12.61	-12.5
Left Convy Sta.	-12.61	-12.5
Left Main Channel	-12.5	
Right Main Channel	12.64	
Right Convy Sta.	11.27	12.64
Right WS Sta.		12.64
L' (left) 0	L (left)	0
L' (Right) 0	L (Right)	0

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT					
Main	25.14	177.02	60.33	2.40	2.94
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1871 Profile: 100 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	Chan	-12.61	-11.02	0.43	0.55	1.66	0.25	0.37	0.79	16.57	13.12
2	Chan	-11.02	-9.42	2.76	1.81	1.78	1.56	1.14	1.52	51.05	77.65
3	Chan	-9.42	-7.83	6.68	3.08	1.78	3.77	1.93	2.17	86.87	188.34
4	Chan	-7.83	-6.24	11.82	4.34	1.78	6.68	2.72	2.73	122.42	333.61
5	Chan	-6.24	-4.65	16.73	5.15	1.62	9.45	3.24	3.25	159.3	517.42
6	Chan	-4.65	-3.06	17.04	5.17	1.59	9.63	3.25	3.3	162.89	537.03
7	Chan	-3.06	-1.46	17.04	5.17	1.59	9.63	3.25	3.3	162.89	537.03
8	Chan	-1.46	0.13	17.04	5.17	1.59	9.63	3.25	3.3	162.89	537.03
9	Chan	0.13	1.72	17.04	5.17	1.59	9.63	3.25	3.3	162.89	537.03
10	Chan	1.72	3.31	17.04	5.17	1.59	9.63	3.25	3.3	162.89	537.03
11	Chan	3.31	4.91	17.04	5.17	1.59	9.63	3.25	3.3	162.89	537.03
12	Chan	4.91	6.5	16.3	5.11	1.65	9.21	3.21	3.19	155.22	495.53
13	Chan	6.5	8.09	10.92	4.14	1.78	6.17	2.6	2.64	116.66	307.87
14	Chan	8.09	9.68	6.26	2.95	1.76	3.54	1.85	2.12	84.08	178.35
15	Chan	9.68	11.27	2.53	1.72	1.78	1.43	1.08	1.47	48.46	71.2
16	Chan	11.27	12.87	0.35	0.46	1.53	0.2	0.34	0.75	15.22	11.37
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BRIDGE SECTION

River Station 1807.5 BR U

CROSS SECTION OUTPUT

Use the same data as in the contraction scour computation? Yes

Plan: PR_DOT Mad River Reach 1 RS: 1807.5 BR U Profile: 100 Year

E.G. Elev (m)	113.69	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.45	Wt. n-Val.	0.08	0.04	0.04	
W.S. Elev (m)	113.24	Reach Len. (m)	58.8	58.8	58.8	
Crit W.S. (m)	112.44	Flow Area (m2)	0.22	59.45	0.24	
E.G. Slope (m/m)	0.004547	Area (m2)	0.22	59.45	0.24	59.91
Q Total (m3/s)	176.98	Flow (m3/s)	0.07	176.78	0.13	
Top Width (m)	26.01	Top Width (m)	1.03	23.97	1.01	
Vel Total (m/s)	2.95	Avg. Vel. (m/s)	0.3	2.97	0.56	
Max Chl Dpth (m)	3.23	Hydr. Depth (m)	0.21	2.48	0.24	2.30
Conv. Total (m3/s)	2624.6	Conv. (m3/s)	1	2621.6	2	
Length Wtd. (m)	58.8	Wetted Per. (m)	1.03	25.38	1.25	
Min Ch El (m)	110.01	Shear (N/m2)	9.44	104.45	8.55	
Alpha	1.01	Stream Power (N/m s)	620.97	0	0	
Frctn Loss (m)	0.29	Cum Volume (1000 m3)	9.81	59.68	4.22	
C & E Loss (m)	0	Cum SA (1000 m2)	23.45	25.47	6.45	

	Flow dis.	*manual*
Left WS Sta.	-14.2	-14.93
Left Flood Sta.		-14.2
Left Main Channel	-13.04	
Right Main Channel	12.97	
Right Flood Sta.		13.2
Right WS Sta.	12.97	13.5
L' (left) 1.16	L (left)	1.89
L' (Right) 0.23	L (Right)	0.53

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		0.07	0.22		
Main	26.01	176.73	59.51	2.29	2.97
Right		0.09	0.18		

Plan: PR_DOT Mad River Reach 1 RS: 1807.5 BR U Profile: 100 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	LOB	-14.2	-12.01	0.07	0.22	1.03	0.04	0.21	0.3	9.44	2.82
2	Chan	-12.01	-10.81	0.6	0.64	1.34	0.34	0.53	0.93	21.36	19.92
3	Chan	-10.81	-9.61	2.08	1.36	1.34	1.18	1.13	1.54	45.16	69.38
4	Chan	-9.61	-8.41	4.22	2.07	1.34	2.38	1.73	2.04	68.97	140.5
5	Chan	-8.41	-7.22	6.91	2.79	1.34	3.91	2.32	2.48	92.77	230.31
6	Chan	-7.22	-6.02	10.12	3.5	1.34	5.72	2.92	2.89	116.58	337.01
7	Chan	-6.02	-4.82	12.85	3.87	1.2	7.26	3.23	3.32	143.64	477.26
8	Chan	-4.82	-3.62	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
9	Chan	-3.62	-2.42	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
10	Chan	-2.42	-1.22	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
11	Chan	-1.22	-0.02	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
12	Chan	-0.02	1.17	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
13	Chan	1.17	2.37	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
14	Chan	2.37	3.57	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
15	Chan	3.57	4.77	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
16	Chan	4.77	5.97	12.86	3.87	1.2	7.27	3.23	3.33	143.89	478.63
17	Chan	5.97	7.17	10.25	3.53	1.34	5.79	2.94	2.91	117.61	341.99
18	Chan	7.17	8.36	6.99	2.81	1.34	3.95	2.34	2.49	93.31	232.56
19	Chan	8.36	9.56	4.26	2.09	1.34	2.41	1.74	2.04	69.35	141.81
20	Chan	9.56	10.76	2.1	1.36	1.34	1.19	1.14	1.54	45.39	69.96
21	Chan	10.76	11.96	0.6	0.64	1.34	0.34	0.54	0.93	21.42	20.02
22	ROB	11.96	12.06	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
23	ROB	12.06	12.16	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
24	ROB	12.16	12.26	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
25	ROB	12.26	12.36	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
26	ROB	12.36	12.46	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
27	ROB	12.46	12.57	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
28	ROB	12.57	12.67	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
29	ROB	12.67	12.77	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
30	ROB	12.77	12.87	0.01	0.02	0.1	0.01	0.24	0.59	10.56	6.27
31	ROB	12.87	12.97	0.01	0.02	0.34	0	0.24	0.27	3.16	0.84
32											
33											

BRIDGE OUTPUT

River Station 1807.5

Low Chord Elev. 114.01
Mean Channelbed Elev. 110.01

Plan: PR_DOT Mad River Reach 1 RS: 1807.5 Profile: 100 Year

E.G. US. (m)	113.85	Element	Inside BR US	Inside BR DS
W.S. US. (m)	113.42	E.G. Elev (m)	113.69	113.39
Q Total (m3/s)	176.98	W.S. Elev (m)	113.24	112.94
Q Bridge (m3/s)	176.98	Crit W.S. (m)	112.44	112.16
Q Weir (m3/s)		Max Chl Dpth (m)	3.23	3.21
Weir Sta Lft (m)		Vel Total (m/s)	2.95	3
Weir Sta Rgt (m)		Flow Area (m2)	59.91	59.08
Weir Submerg		Froude # Chl	0.6	0.62
Weir Max Depth (m)		Specif Force (m3)	138.51	137.74
Min El Weir Flow (m)	115.82	Hydr Depth (m)	2.3	2.38
Min El Prs (m)	114.32	W.P. Total (m)	27.66	26.33
Delta EG (m)	0.65	Conv. Total (m3/s)	2624.6	2410.6
Delta WS (m)	0.69	Top Width (m)	26.01	24.82
BR Open Area (m2)	80.74	Frctn Loss (m)	0.29	0.19
BR Open Vel (m/s)	3	C & E Loss (m)	0	0.01
Coef of Q		Shear Total (N/m2)	96.59	118.59
Br Sel Method	Energy only	Power Total (N/m s)	-1287.92	-598.95

PROJECT NO. 151-273 **BRIDGE NO.** 05774 **UNIT:** Metric

Ref. HEC-18., May 2001 (4th ed.)

SUMMARY

Contraction Scour		Type:	**LIVE-BED**	Depth:	**0.55** m	Event:	**500-YR**
Local	**West Abut. #1**	**LEFT**	Eq.: Froehlich	Depth:	**0.73** m	Event:	**500-YR**
Abutment	**East Abut. #2**	**RIGHT**	Eq.: Froehlich	Depth:	**0.60** m	Event:	**500-YR**

CONTRACTION SCOUR

$V_c = K_u y^{1/6} D^{1/3}$ .....Eq. 5.1

= 0.54 *m/s* Critacal velocity above which bed material of size D and smaller will be transported

Ku = 6.19 m (6.19 in SI units; 11.17 in English units)

y = 3.73 m Average depth of flow upstream of the bridge

D = 0.00034 m Particle size for Vc *, m* (use D_{50})

V1 = 3.29 *m/s* The mean velocity of the flow in the main channel or overbank area upstream of the brige opening

Vc < V1 ***Thus, LIVE-BED CONTRACTION SCOUR***

Live-Bed Contraction Scour ==========

$Y_2/Y_1 = (Q_2/Q_1)^{6/7} (W_1/W_2)^{k_1}$ = 1.03 .....Eq. 5.2

$Y_s = Y_2 - Y_o$ m .....Eq. 5.3

= 0.55 m Average contraction scour depth

Y_1 = 3.73 m Average depth in the upstream main channel

Y_2 = 3.84 m Average depth in the contracted section

Y_o = 3.28 m Existing depth in the contracted section before scour

Q_1 = 259.71 m3/s Flow in the upstream channel transporting sediment

Q_2 = 268.51 m3/s Flow in the contracted channel

W_1 = 12.00 m Bottom width of the upstream main channel that is transporting bed material

W_2 = 12.00 m Bottom width of the main channel in the contracted section less pier width

k_1 = 0.69 Exponent determined below (V^*/ω = 7.25)

V^* = 0.3626 $=(T_o/\rho)^{1/2}$ or $(gY1\ S1)^{1/2}$, shear velocity in the upstream section , m/s

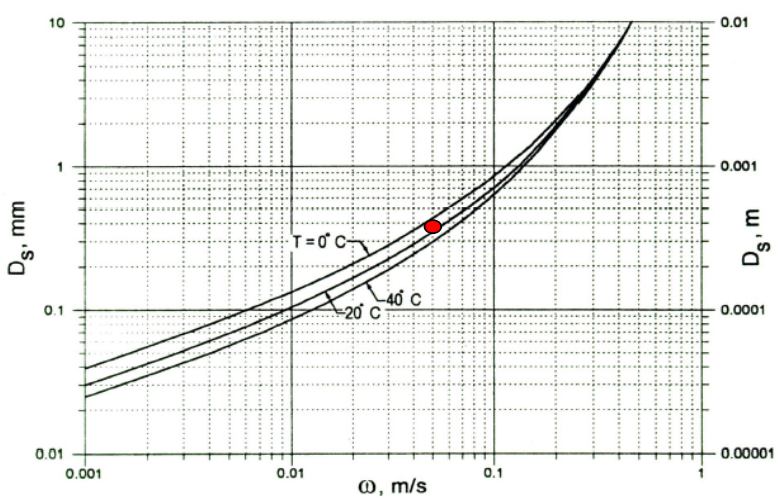
ω = 0.05 m/s Fall velocity of bed material based on the D_{50} (Figure 5.8)

g = 9.81 m/s^2 Acceleration of gravity

S1 = 0.002198 m/m Slope of energy gradeline of main channel

T_o = 131.46 Pa (N/m^2) Shear stess on the bed

ρ = 1000 kg/m^3 Density of water



V^*/ω	k1	*Mode of Bed Material Transport*
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

Figure 5.8. Fall velocity of sand-sized particles with specific gravity of 2.65 in metric units.

Clear-Water Contraction Scour ==========

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2} \right]^{3/7}$$ .....Eq. 5.4

$$y_s = y_2 - y_o$$ **m** .....Eq. 5.5

=	**N/A**	**m**	Average contraction scour depth **LIVE-BED controls. Ignore this procedure**
y_2 =	27.19	m	Average equilibrium depth in the contracted section after contraction scour
y_o =	3.28	m	Average existing depth in the contracted section
Q =	269.01	m3/s	Discharge through the bridge or on the set-back overbank area at the bridge associated with the width W
W =	12.00	m	Bottom width of the contracted section less pier widths
K_u =	0.0250		(0.025 in SI units; 0.0077 in English units)
D_m =	0.0004	m	Diameter of the smallest nontransportable particle in the bed material (1.25 D_{50}) in th contacted setion
D_{50} =	0.0003	m	Median diameter of bed material

Because D_{50} is not the largest particle in the bed material, the scoured section can be slightly armored. Therefore, the D_m is assumed to be 1.25 D_{50}. For stratified bed material the depth of scour can be determined by using the clear-water scour equation sequentially with successive D_m of the bed material layers.

Data Source

Eq. 5.1			From:	RS
y =	3.73	m	D	1900
V1 =	3.29	m	D	1807.5 BR U

Eq. 5.2 & 5.3					
Y1 =	3.73	m	D	1900	From Flow Distribution Columns where V > 1 m/s
Yo =	3.28	m	D	1807.5 BR U	
Q1 =	259.71	m3/s	D	1900	
Q2 =	268.51	m3/s	D	1807.5 BR U	
W1 =	enter bottom	m	M	1900	
or	12	m (manual)			
W2 =	enter bottom	m	M	1807.5 BR U	
or	12	m (manual)			
S1 =	0.002198	m/m	C	1900	
To =	131.46	Pa (N/m^2)	C	1807.5 BR U	
P2 =	0	m (pier width)			

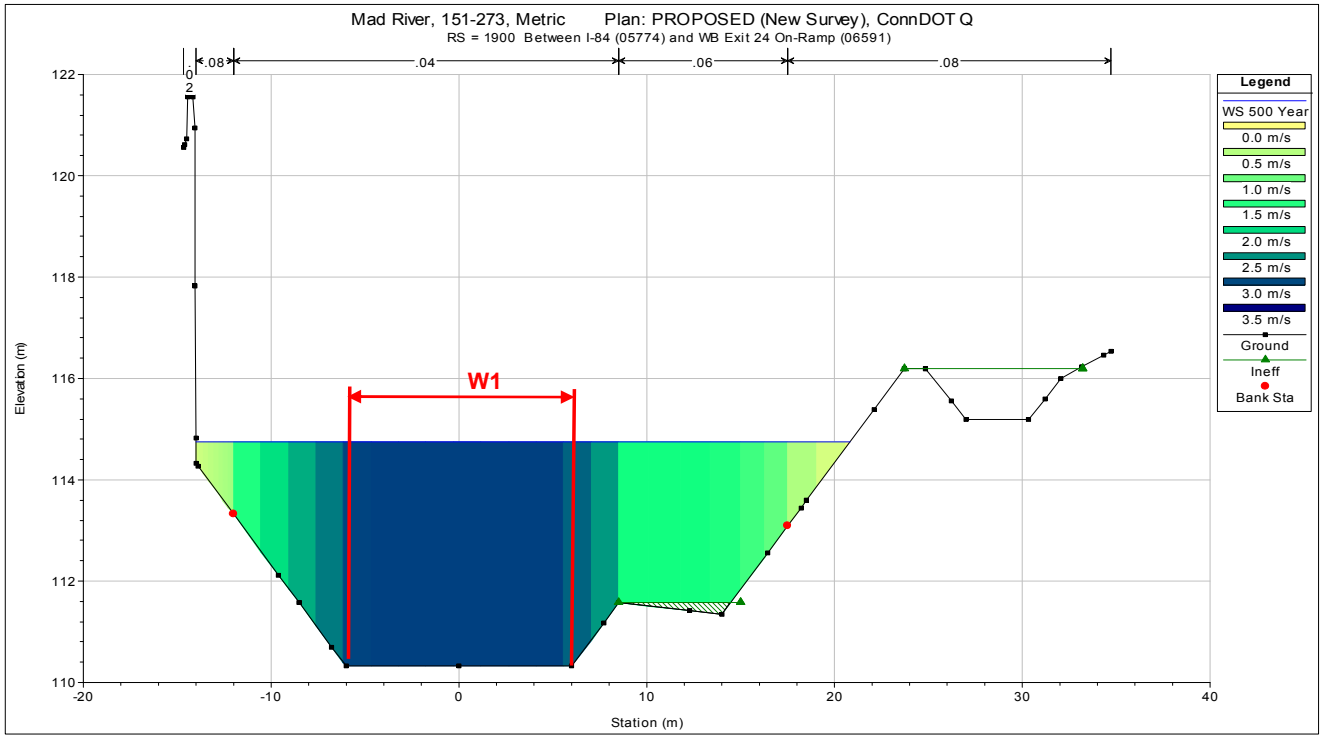
Eq. 5.4 & 5.5				
Q =	269.01	m3/s	C	1807.5

Legends:

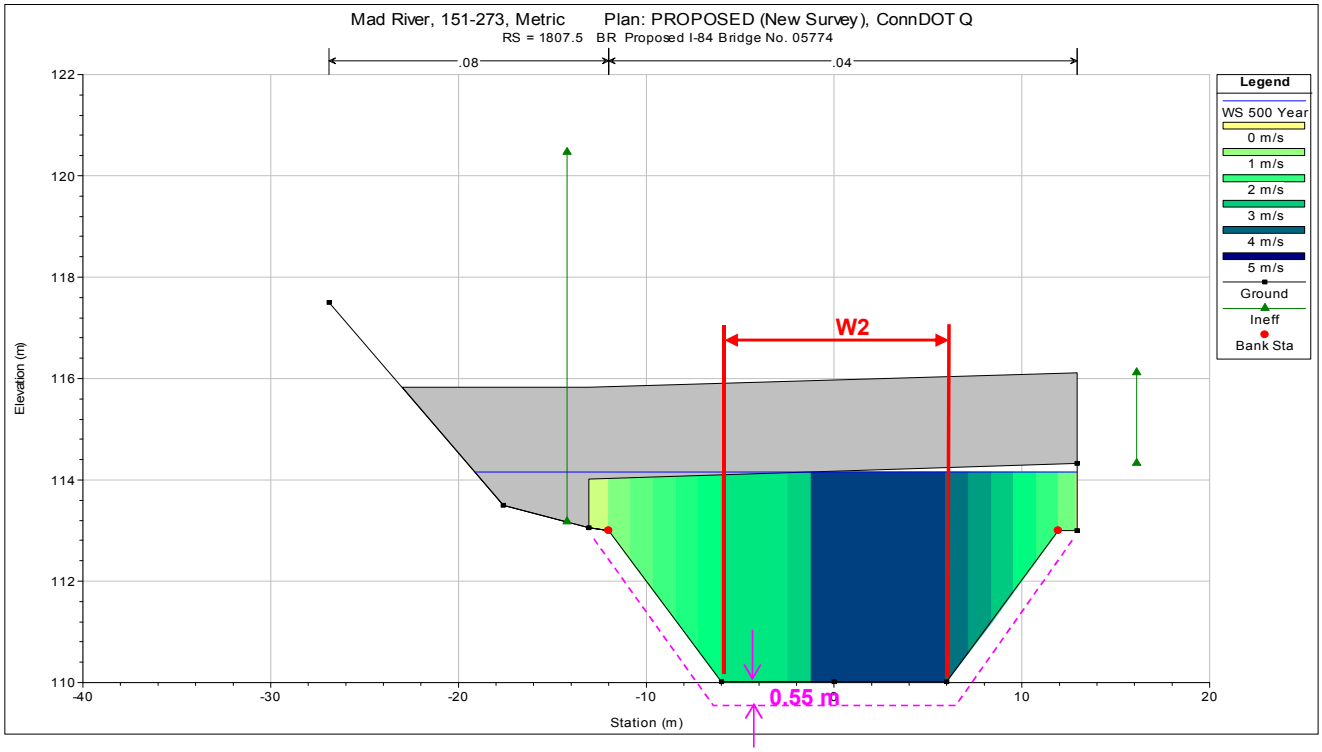
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections used for Constraction Scour Computations

UPSTREAM SECTION **1900**



CONTRACTED SECTION **1807.5 BR U**



UPSTREAM CHANNEL SECTION

River Station 1900 Event: 500-YR

HEC-RAS CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1900 Profile: 500 Year

		Element	Left OB	Channel	Right OB	Total
E.G. Elev (m)	115.06	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.32	Wt. n-Val.	0.08	0.043	0.08	
W.S. Elev (m)	114.75	Reach Len. (m)	29.4	29.4	29.4	
Crit W.S. (m)		Flow Area (m2)	1.85	106.51	2.72	
E.G. Slope (m/m)	0.002198	Area (m2)	1.85	107.17	2.72	111.74
Q Total (m3/s)	269.01	Flow (m3/s)	0.96	266.76	1.3	
Top Width (m)	34.84	Top Width (m)	2.01	29.53	3.3	
Vel Total (m/s)	2.42	Avg. Vel. (m/s)	0.52	2.5	0.48	
Max Chl Dpth (m)	4.43	Hydr. Depth (m)	0.92	3.61	0.82	3.21
Conv. Total (m3/s)	5737.7	Conv. (m3/s)	20.4	5689.6	27.7	
Length Wtd. (m)	29.4	Wetted Per. (m)	2.66	30.95	3.69	
Min Ch El (m)	110.32	Shear (N/m2)	15	74.18	15.89	
Alpha	1.06	Stream Power (N/m s)	1661.36	0	0	
Frctn Loss (m)	0.1	Cum Volume (1000 m3)	34.24	82.49	12.31	
C & E Loss (m)	0.05	Cum SA (1000 m2)	48.41	27.04	14.53	

	Flow dis.	*manual*
Left WS Sta.	-22	-14.02
Left Convy Sta.	-12.01	-14.02
Left Main Channel	-12.01	
Right Main Channel	15	
Right Convy Sta.	17.52	20.82
Right WS Sta.		20.82

L' (left)	2.01	L (left)	2.01
L' (Right)	5.82	L (Right)	5.82

HEC-RAS FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		0.96	1.85		
Main	27.01	259.71	100.76	3.73	2.58
Right		1.3	2.72		

Plan: PR_DOT Mad River Reach 1 RS: 1900 Profile: 500 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	LOB	-14.11	-13.85	0.02	0.08	0.6	0.01	0.45	0.3	2.71	0.82
2	LOB	-13.85	-13.59	0.05	0.15	0.29	0.02	0.57	0.36	11	3.91
3	LOB	-13.59	-13.32	0.08	0.18	0.29	0.03	0.7	0.41	13.54	5.52
4	LOB	-13.32	-13.06	0.1	0.22	0.29	0.04	0.83	0.46	16.07	7.35
5	LOB	-13.06	-12.8	0.13	0.25	0.29	0.05	0.97	0.5	18.61	9.38
6	LOB	-12.8	-12.54	0.16	0.29	0.29	0.06	1.1	0.55	21.14	11.61
7	LOB	-12.54	-12.27	0.19	0.32	0.29	0.07	1.23	0.59	23.68	14.02
8	LOB	-12.27	-12.01	0.23	0.36	0.29	0.08	1.36	0.63	26.21	16.61
9	Chan	-12.01	-10.55	4.08	2.63	1.64	1.52	1.79	1.55	34.54	53.68
10	Chan	-10.55	-9.08	7.24	3.7	1.64	2.69	2.53	1.96	48.74	95.3
11	Chan	-9.08	-7.62	11.04	4.77	1.64	4.1	3.25	2.31	62.8	145.38
12	Chan	-7.62	-6.15	15.48	5.84	1.64	5.75	3.99	2.65	76.91	203.8
13	Chan	-6.15	-4.69	19.65	6.48	1.48	7.3	4.42	3.03	94.2	285.74
14	Chan	-4.69	-3.22	19.83	6.48	1.46	7.37	4.43	3.06	95.39	291.8
15	Chan	-3.22	-1.76	19.83	6.48	1.47	7.37	4.43	3.06	95.39	291.8
16	Chan	-1.76	-0.29	19.83	6.48	1.46	7.37	4.43	3.06	95.39	291.8
17	Chan	-0.29	1.17	19.83	6.48	1.46	7.37	4.43	3.06	95.39	291.8
18	Chan	1.17	2.64	19.83	6.48	1.47	7.37	4.43	3.06	95.39	291.8
19	Chan	2.64	4.1	19.83	6.48	1.46	7.37	4.43	3.06	95.39	291.8
20	Chan	4.1	5.57	19.83	6.48	1.46	7.37	4.43	3.06	95.39	291.8
21	Chan	5.57	7.03	17.54	6.22	1.59	6.52	4.24	2.82	84.5	238.42
22	Chan	7.03	8.5	12.71	5.19	1.64	4.73	3.54	2.45	68.29	167.16
23	Chan	8.5	10.13	8.43	5.16	1.63	3.13	3.18	1.63	68.4	111.73
24	Chan	10.13	11.75	8.43	5.16	1.63	3.13	3.18	1.63	68.4	111.73
25	Chan	11.75	13.38	8.43	5.16	1.63	3.13	3.18	1.63	68.4	111.73
26	Chan	13.38	15	7.87	5.09	1.74	2.92	3.13	1.55	62.98	97.38
27	Chan	15	16.26	4.32	3.26	1.41	1.61	2.59	1.32	49.94	66.16
28	Chan	16.26	17.52	2.72	2.47	1.41	1.01	1.96	1.1	37.8	41.58
29	ROB	17.52	19.07	1.08	1.96	1.74	0.4	1.26	0.55	24.31	13.41
30	ROB	19.07	20.62	0.22	0.75	1.73	0.08	0.48	0.29	9.32	2.71
31	ROB	20.62	22.18	0	0.01	0.21	0	0.05	0.06	0.92	0.06
32	ROB										
33	ROB										
34	ROB										
35	ROB										
36	ROB										
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CONTRACTED CHANNEL SECTION

River Station 1807.5 BR U

CROSS SECTION OUTPUT

As the flow comes in contact with the low chord, the data here should not be used as-is.

Plan: PR_DOT Mad River Reach 1 RS: 1807.5 BR U Profile: 500 Year

			Left OB	Channel	Right OB	Total
E.G. Elev (m)	114.7	Element				
Vel Head (m)	0.56	Wt. n-Val.	0.08	0.04	0.04	
W.S. Elev (m)	114.15	Reach Len. (m)	58.8	58.8	58.8	
Crit W.S. (m)	113.11	Flow Area (m2)	1.02	80.64	1.16	
E.G. Slope (m/m)	0.005975	Area (m2)	1.02	80.64	1.16	82.82
Q Total (m3/s)	269.01	Flow (m3/s)	0.48	267.05	1.48	
Top Width (m)	14.42	Top Width (m)		13.41	1.01	
Vel Total (m/s)	3.25	Avg. Vel. (m/s)	0.47	3.31	1.28	
Max Chl Dpth (m)	4.14	Hydr. Depth (m)		6.01	1.15	5.74
Conv. Total (m3/s)	3480.1	Conv. (m3/s)	6.2	3454.7	19.2	
Length Wtd. (m)	58.8	Wetted Per. (m)	3.02	35.94	2.16	
Min Ch El (m)	110.01	Shear (N/m2)	19.8	131.46	31.48	
Alpha	1.03	Stream Power (N/m s)	620.97	0	0	
Frctn Loss (m)	0.38	Cum Volume (1000 m3)	34.2	76.73	12.25	
C & E Loss (m)	0.01	Cum SA (1000 m2)	48.38	25.44	14.47	

	Flow dis.	*manual*
Left WS Sta.	-14.2	-19.1
Left Flood Sta.	-12.01	-13.04
Left Main Channel	-12.01	
Right Main Channel	12.87	
Right Flood Sta.	10.76	12.87
Right WS Sta.		12.97

L' (left)	1.03	L (left)	7.09
L' (Right)	0	L (Right)	0.1

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		0.48	1.02		
Main	24.88	268.51	81.72	3.28	3.29
Right		0.03	0.12		

Plan: PR_DOT Mad River Reach 1 RS: 1807.5 BR U Profile: 500 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	LOB	-14.2	-12.01	0.48	1.02	3.02	0.18	0.99	0.47	19.8	9.28
2	Chan	-12.01	-10.81	1.98	1.59	2.54	0.74	1.33	1.24	36.75	45.68
3	Chan	-10.81	-9.61	3.72	2.32	2.54	1.38	1.94	1.6	53.65	85.82
4	Chan	-9.61	-8.41	5.87	3.05	2.54	2.18	2.55	1.92	70.55	135.45
5	Chan	-8.41	-7.22	8.39	3.79	2.54	3.12	3.16	2.22	87.45	193.74
6	Chan	-7.22	-6.02	11.26	4.52	2.54	4.19	3.77	2.49	104.35	260.08
7	Chan	-6.02	-4.82	13.4	4.9	2.4	4.98	4.09	2.73	119.75	327.17
8	Chan	-4.82	-3.62	13.48	4.92	2.4	5.01	4.11	2.74	120.27	329.56
9	Chan	-3.62	-2.42	13.56	4.94	2.4	5.04	4.12	2.75	120.69	331.47
10	Chan	-2.42	-1.22	14.57	4.95	2.17	5.41	4.13	2.94	133.67	393
11	Chan	-1.22	-0.02	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
12	Chan	-0.02	1.17	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
13	Chan	1.17	2.37	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
14	Chan	2.37	3.57	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
15	Chan	3.57	4.77	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
16	Chan	4.77	5.97	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
17	Chan	5.97	7.17	17.91	4.62	1.34	6.66	3.85	3.88	202.42	784.77
18	Chan	7.17	8.36	13.47	3.9	1.34	5.01	3.25	3.46	170.36	588.74
19	Chan	8.36	9.56	9.58	3.18	1.34	3.56	2.65	3.02	138.87	418.78
20	Chan	9.56	10.76	6.24	2.46	1.34	2.32	2.05	2.54	107.38	272.79
21	Chan	10.76	11.96	3.5	1.74	1.34	1.3	1.45	2.02	75.89	152.96
22	ROB	11.96	12.06	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
23	ROB	12.06	12.16	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
24	ROB	12.16	12.26	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
25	ROB	12.26	12.36	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
26	ROB	12.36	12.46	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
27	ROB	12.46	12.57	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
28	ROB	12.57	12.67	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
29	ROB	12.67	12.77	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
30	ROB	12.77	12.87	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
31	ROB	12.87	12.97	0.03	0.12	1.25	0.01	1.15	0.26	5.44	1.41
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LIVE SCOUR AT ABUTMENTS

Froehlich's Live-Bed Abutment Scour Equation — *LEFT* — *RIGHT* — ==========

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 1 =$ — **2.46** — **2.26** — .....Eq. 7.1

Amended Local Scour Equation

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 0.05 =$ — **1.51** — **1.31** — .....CT DOT DM Pg 9B-2

	LEFT	*RIGHT*		
Ys =	**0.73**	**0.60**	**m**	Scour depth <== using Amended equation
K_1 =	1.00	1.00		Coeffcient for abutment shape (see Table 7.1 and Figrue 7.6)
K_2 =	1.05	0.91		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
θ =	135	45		
				θ < 90 degrees if embankment points downstream
				θ > 90 degrees if embankment points upstream
				(see Figure 7.5 for definition of θ)
L' =	1.59	1.59	m	Length of active flow obstructed by the embankment (see Figure 7.4)
Ae =	0.95	0.84	m^2	Flow area of the approach cross section obstructed by the embankment
Fr =	0.19	0.19		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment
Ve =	0.42	0.39	m/s	Qe/Ae
Qe =	0.4	0.33	m^3/s	Flow obstructed by the abutment and approach embankment
Ya =	0.49	0.46	m	Ae/L, Average depth of flow on the floodplain
L =	1.95	1.83	m	Length of embankment projected normal to the flow

Table 7.1. Abutment Shape Coefficients.

Description	K_1
Vertical-wall abutment	1.00
Vertical-wall abutment with wing walls	0.82
Spill-through abutment	0.55

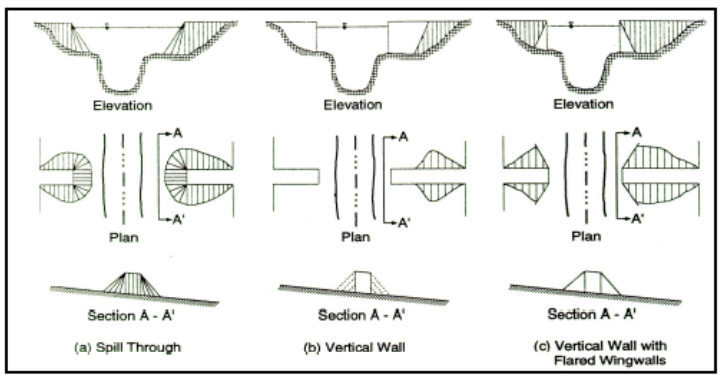


Figure 7.6. Abutment shape.

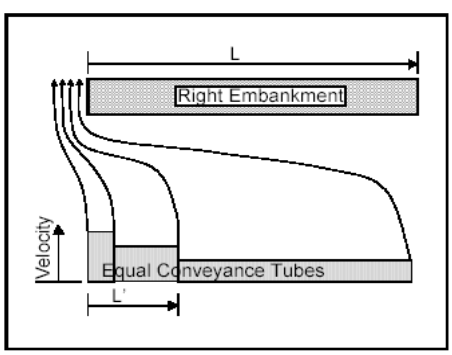


Figure 7.4. Determination of length of embankment blocking live flow for abutment scour estimation.

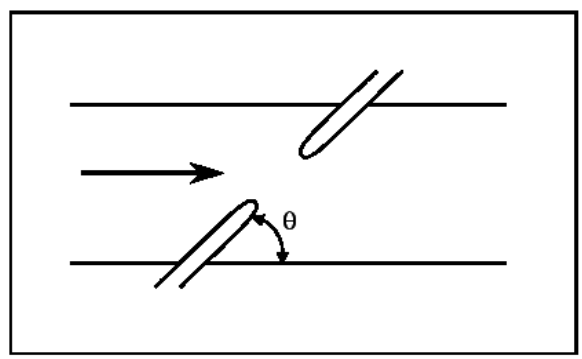


Figure 7.5. Orientation of embankment angle, θ, to the flow.

HIRE Live-Bed Abutment Scour Equation ==========

		LEFT	RIGHT	
Applicability check:	L/Y_1 =	1	0	*Use HIRE Eq. only if L/Y_1 > 25*
$Y_s/Y_1 = 4\ Fr^{0.33}\ K_1/0.55\ K_2$ =		**N/A**	**N/A**	.....Eq. 7.1

	LEFT	RIGHT		
Y_s =	**N/A**	**N/A**	**m**	Scour depth (N/A if L/Y_1 < 25)
K1 =	1.00	1.00		Coeffcient for abutment shape (see Table 7.1 on RIGHT)
K2 =	1.05	0.91		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
Y1 =	3.73	3.73	m	Depth of flow at the abutment on the overbank or in the main channel,
Fr =	0.19	0.19		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment

Data Source

Eq. 7.1				From:	RS
LT				UC	
	L' =	1.59	m	D	1871
	Ae =	0.95	m2	D	1871
	Qe =	0.4	m3/s	D	1871
	L =	1.95	m	D	1871
RT				UC	
	L' =	1.59	m	D	1871
	Ae =	0.84	m2	D	1871
	Qe =	0.33	m3/s	D	1871
	L =	1.83	m	D	1871

Legends:

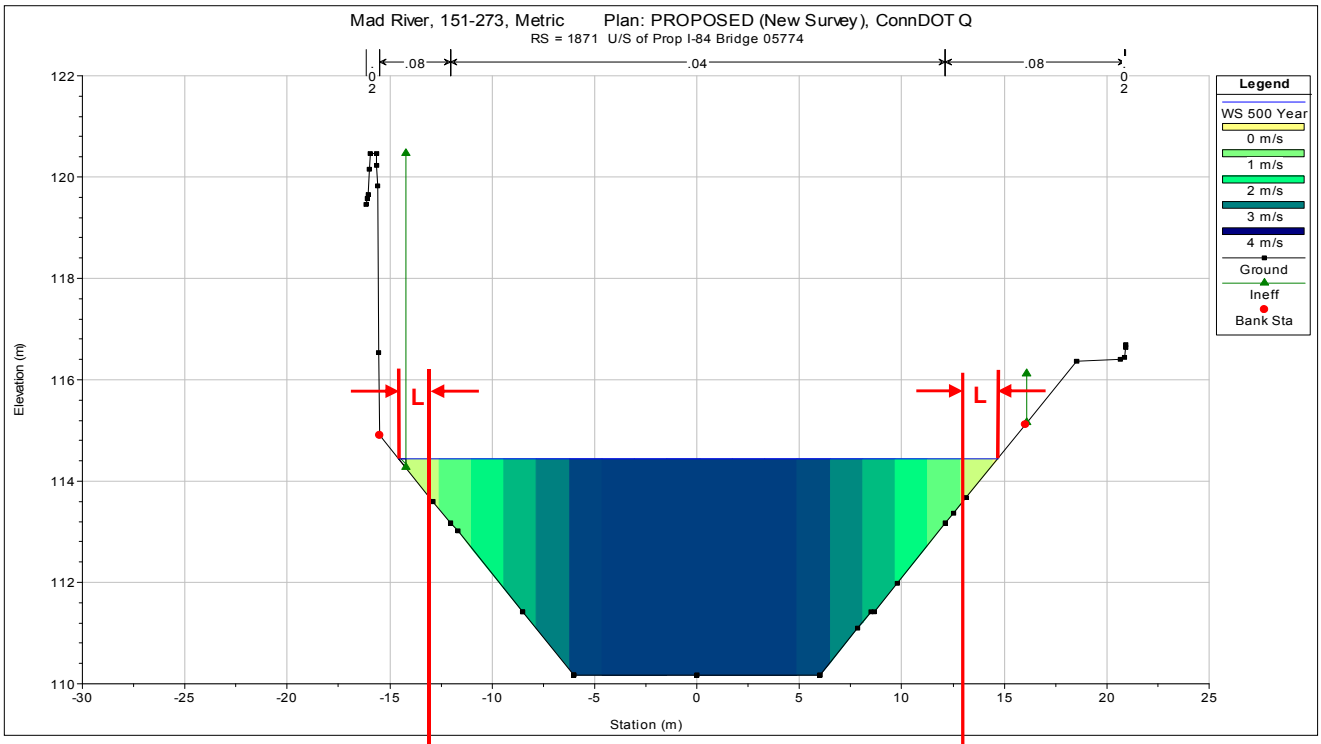
UC	from an upstream Cross Section output (approach section)
UF	from Bridge Upstream Face - Cross Section output (BR U); or Bridge Downstream Face (BR D) - this is seldom used
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

$$Y_s/Y_1 = -5.08 + 1.27\,(Y_1/H_b) + 4.44\,(H_b/Y_1) + 0.19\,(V_a/V_c) =$$ **less than zero m**

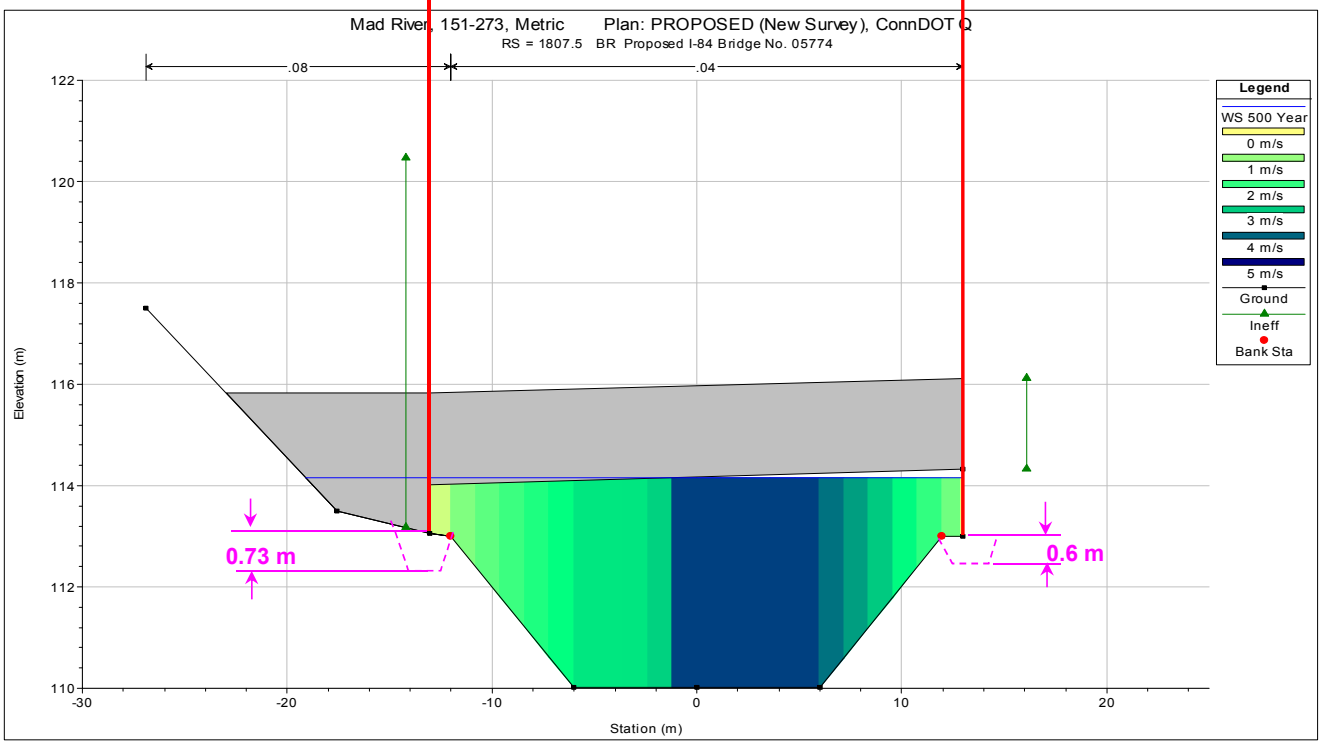
Y_s =	**N/A**	**m**	Depth of vertical contraction scour relative to mean bed elevation
Y_1 =	5.74	m	Depth of flow immediately upstream of the bridge (hydraulic depth at upstream face)
H_b =	4.00	m	Distance from the low chord of the bridge to the average elevation of the stream bed before scour
V_a =	3.25	m/s	Average velocity of the flow through the bridge opening before scour occurs
V_c =	8.30	m/s	Critical velocity of the D_{50} of the bed material in the bridge opening
D_{50} = (Design)	1.25	m	if different from the value used in the Constraction Scour computation

Cross Sections Used for Local Abutment Scour Computations

APPROACH SECTION 1871



BRIDGE SECTION 1807.5 BR U



UPSTREAM CHANNEL SECTION

River Station 1871 | Event: 500-YR

CROSS SECTION OUTPUT *Use the same data as in the contraction scour computation?* No

Plan: PR_DOT Mad River Reach 1 RS: 1871 Profile: 500 Year

E.G. Elev (m)	114.92	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.47	Wt. n-Val.		0.048		
W.S. Elev (m)	114.45	Reach Len. (m)	34.24	34.24	34.24	
Crit W.S. (m)	113.26	Flow Area (m2)		88.36		
E.G. Slope (m/m)	0.005258	Area (m2)		88.39		88.39
Q Total (m3/s)	269.01	Flow (m3/s)		269.01		
Top Width (m)	29.26	Top Width (m)		29.26		
Vel Total (m/s)	3.04	Avg. Vel. (m/s)		3.04		
Max Chl Dpth (m)	4.28	Hydr. Depth (m)		3.06		3.02
Conv. Total (m3/s)	3710	Conv. (m3/s)		3710		
Length Wtd. (m)	34.24	Wetted Per. (m)		30.88		
Min Ch El (m)	110.17	Shear (N/m2)		147.53		
Alpha	1	Stream Power (N/m s)	1002.08	0	0	
Frctn Loss (m)	0.19	Cum Volume (1000 m3)	34.22	79.62	12.27	
C & E Loss (m)	0.02	Cum SA (1000 m2)	48.38	26.17	14.49	

	Flow dis.	*manual*
Left WS Sta.	-15.48	-14.56
Left Convy Sta.	-14.2	
Left Main Channel	-12.61	
Right Main Channel	12.87	
Right Convy Sta.	14.46	
Right WS Sta.		14.7
L' (left) 1.59	L (left)	1.95
L' (Right) 1.59	L (Right)	1.83

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		0.4	0.95		
Main	25.48	268.29	86.58	3.40	3.10
Right		0.33	0.84		

Plan: PR_DOT Mad River Reach 1 RS: 1871 Profile: 500 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	Chan	-15.48	-14.2	0	0.03	0.4	0	0.09	0	4.16	0
2	Chan	-14.2	-12.61	0.4	0.92	1.78	0.15	0.58	0.43	26.73	11.5
3	Chan	-12.61	-11.02	2.94	2.19	1.78	1.09	1.37	1.34	63.45	85.12
4	Chan	-11.02	-9.42	7.17	3.46	1.78	2.66	2.17	2.07	100.02	207.51
5	Chan	-9.42	-7.83	12.08	4.72	1.78	4.49	2.97	2.56	136.88	350.04
6	Chan	-7.83	-6.24	17.91	5.98	1.78	6.66	3.76	2.99	173.41	519.19
7	Chan	-6.24	-4.65	23.54	6.8	1.62	8.75	4.27	3.46	215.86	747.87
8	Chan	-4.65	-3.06	23.94	6.81	1.59	8.9	4.28	3.51	220.57	775.26
9	Chan	-3.06	-1.46	23.94	6.81	1.59	8.9	4.28	3.51	220.57	775.26
10	Chan	-1.46	0.13	23.94	6.81	1.59	8.9	4.28	3.51	220.57	775.26
11	Chan	0.13	1.72	23.94	6.81	1.59	8.9	4.28	3.51	220.57	775.26
12	Chan	1.72	3.31	23.94	6.81	1.59	8.9	4.28	3.51	220.57	775.26
13	Chan	3.31	4.91	23.94	6.81	1.59	8.9	4.28	3.51	220.57	775.26
14	Chan	4.91	6.5	23.02	6.75	1.65	8.56	4.24	3.41	210.8	718.85
15	Chan	6.5	8.09	16.91	5.78	1.78	6.29	3.63	2.93	167.46	489.82
16	Chan	8.09	9.68	11.61	4.59	1.76	4.32	2.89	2.53	134.49	339.89
17	Chan	9.68	11.27	6.85	3.36	1.78	2.55	2.11	2.04	97.36	198.38
18	Chan	11.27	12.87	2.62	2.09	1.78	0.98	1.31	1.25	60.65	75.99
19	Chan	12.87	14.46	0.33	0.83	1.78	0.12	0.52	0.4	23.9	9.55
20	Chan	14.46	16.05	0	0.01	0.27	0	0.06	0.1	2.8	0.27
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BRIDGE SECTION

River Station 1807.5 BR U

CROSS SECTION OUTPUT

Use the same data as in the contraction scour computation? Yes

Plan: PR_DOT Mad River Reach 1 RS: 1807.5 BR U Profile: 500 Year

E.G. Elev (m)	114.7	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.56	Wt. n-Val.	0.08	0.04	0.04	
W.S. Elev (m)	114.15	Reach Len. (m)	58.8	58.8	58.8	
Crit W.S. (m)	113.11	Flow Area (m2)	1.02	80.64	1.16	
E.G. Slope (m/m)	0.005975	Area (m2)	1.02	80.64	1.16	82.82
Q Total (m3/s)	269.01	Flow (m3/s)	0.48	267.05	1.48	
Top Width (m)	14.42	Top Width (m)		13.41	1.01	
Vel Total (m/s)	3.25	Avg. Vel. (m/s)	0.47	3.31	1.28	
Max Chl Dpth (m)	4.14	Hydr. Depth (m)		6.01	1.15	5.74
Conv. Total (m3/s)	3480.1	Conv. (m3/s)	6.2	3454.7	19.2	
Length Wtd. (m)	58.8	Wetted Per. (m)	3.02	35.94	2.16	
Min Ch El (m)	110.01	Shear (N/m2)	19.8	131.46	31.48	
Alpha	1.03	Stream Power (N/m s)	620.97	0	0	
Frctn Loss (m)	0.38	Cum Volume (1000 m3)	34.2	76.73	12.25	
C & E Loss (m)	0.01	Cum SA (1000 m2)	48.38	25.44	14.47	

	Flow dis.	*manual*
Left WS Sta.	-14.2	-19.1
Left Flood Sta.	-12.01	-13.04
Left Main Channel	-13.04	
Right Main Channel	12.97	
Right Flood Sta.	10.76	12.87
Right WS Sta.		12.97
L' (left)	0	L (left) 6.06
L' (Right)	-0.1	L (Right) 0

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT					
Main	26.01	268.99	82.74	3.18	3.25
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1807.5 BR U Profile: 500 Year

Pos		Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	LOB	-14.2	-12.01	0.48	1.02	3.02	0.18	0.99	0.47	19.8	9.28
2	Chan	-12.01	-10.81	1.98	1.59	2.54	0.74	1.33	1.24	36.75	45.68
3	Chan	-10.81	-9.61	3.72	2.32	2.54	1.38	1.94	1.6	53.65	85.82
4	Chan	-9.61	-8.41	5.87	3.05	2.54	2.18	2.55	1.92	70.55	135.45
5	Chan	-8.41	-7.22	8.39	3.79	2.54	3.12	3.16	2.22	87.45	193.74
6	Chan	-7.22	-6.02	11.26	4.52	2.54	4.19	3.77	2.49	104.35	260.08
7	Chan	-6.02	-4.82	13.4	4.9	2.4	4.98	4.09	2.73	119.75	327.17
8	Chan	-4.82	-3.62	13.48	4.92	2.4	5.01	4.11	2.74	120.27	329.56
9	Chan	-3.62	-2.42	13.56	4.94	2.4	5.04	4.12	2.75	120.69	331.47
10	Chan	-2.42	-1.22	14.57	4.95	2.17	5.41	4.13	2.94	133.67	393
11	Chan	-1.22	-0.02	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
12	Chan	-0.02	1.17	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
13	Chan	1.17	2.37	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
14	Chan	2.37	3.57	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
15	Chan	3.57	4.77	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
16	Chan	4.77	5.97	21.69	4.96	1.2	8.06	4.14	4.37	242.49	1060.41
17	Chan	5.97	7.17	17.91	4.62	1.34	6.66	3.85	3.88	202.42	784.77
18	Chan	7.17	8.36	13.47	3.9	1.34	5.01	3.25	3.46	170.36	588.74
19	Chan	8.36	9.56	9.58	3.18	1.34	3.56	2.65	3.02	138.87	418.78
20	Chan	9.56	10.76	6.24	2.46	1.34	2.32	2.05	2.54	107.38	272.79
21	Chan	10.76	11.96	3.5	1.74	1.34	1.3	1.45	2.02	75.89	152.96
22	ROB	11.96	12.06	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
23	ROB	12.06	12.16	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
24	ROB	12.16	12.26	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
25	ROB	12.26	12.36	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
26	ROB	12.36	12.46	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
27	ROB	12.46	12.57	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
28	ROB	12.57	12.67	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
29	ROB	12.67	12.77	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
30	ROB	12.77	12.87	0.16	0.12	0.1	0.06	1.15	1.39	67.28	93.54
31	ROB	12.87	12.97	0.03	0.12	1.25	0.01	1.15	0.26	5.44	1.41

BRIDGE OUTPUT

River Station 1807.5

Low Chord Elev. 114.01
Mean Channelbed Elev. 110.01

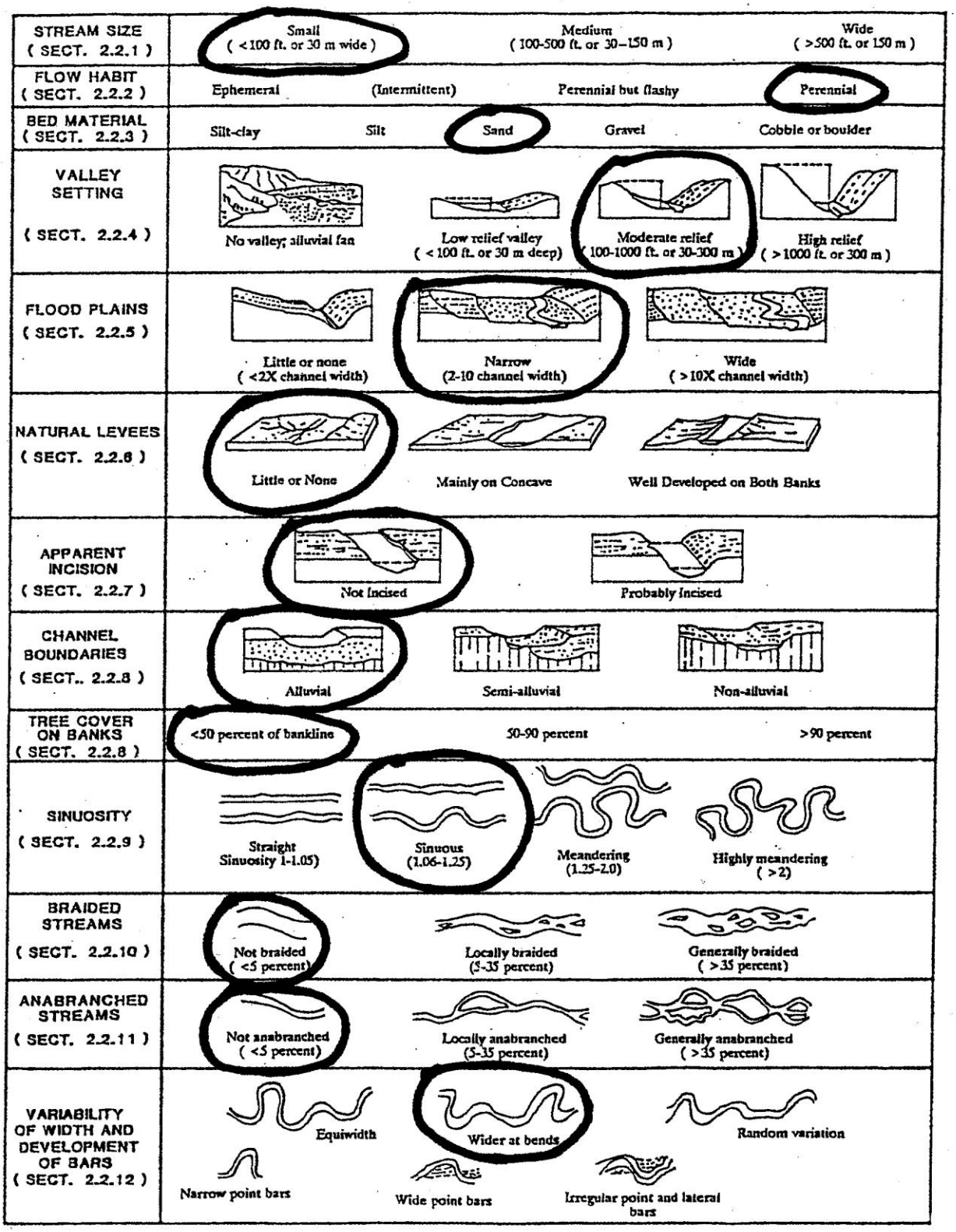
Plan: PR_DOT Mad River Reach 1 RS: 1807.5 Profile: 500 Year

E.G. US. (m)	114.92	Element	Inside BR US	Inside BR DS
W.S. US. (m)	114.45	E.G. Elev (m)	114.7	114.31
Q Total (m3/s)	269.01	W.S. Elev (m)	114.15	113.71
Q Bridge (m3/s)	269.01	Crit W.S. (m)	113.11	112.83
Q Weir (m3/s)		Max Chl Dpth (m)	4.14	3.98
Weir Sta Lft (m)		Vel Total (m/s)	3.25	3.42
Weir Sta Rgt (m)		Flow Area (m2)	82.82	78.65
Weir Submerg		Froude # Chl	0.52	0.55
Weir Max Depth (m)		Specif Force (m3)	240.64	230.78
Min El Weir Flow (m)	115.82	Hydr Depth (m)	5.74	4.12
Min El Prs (m)	114.32	W.P. Total (m)	41.12	35.36
Delta EG (m)	0.85	Conv. Total (m3/s)	3480.1	3190.5
Delta WS (m)	1	Top Width (m)	14.42	19.09
BR Open Area (m2)	80.74	Frctn Loss (m)	0.38	0.22
BR Open Vel (m/s)	3.42	C & E Loss (m)	0.01	0.01
Coef of Q		Shear Total (N/m2)	118.01	155.05
Br Sel Method	Energy only	Power Total (N/m s)	-1287.92	-598.95

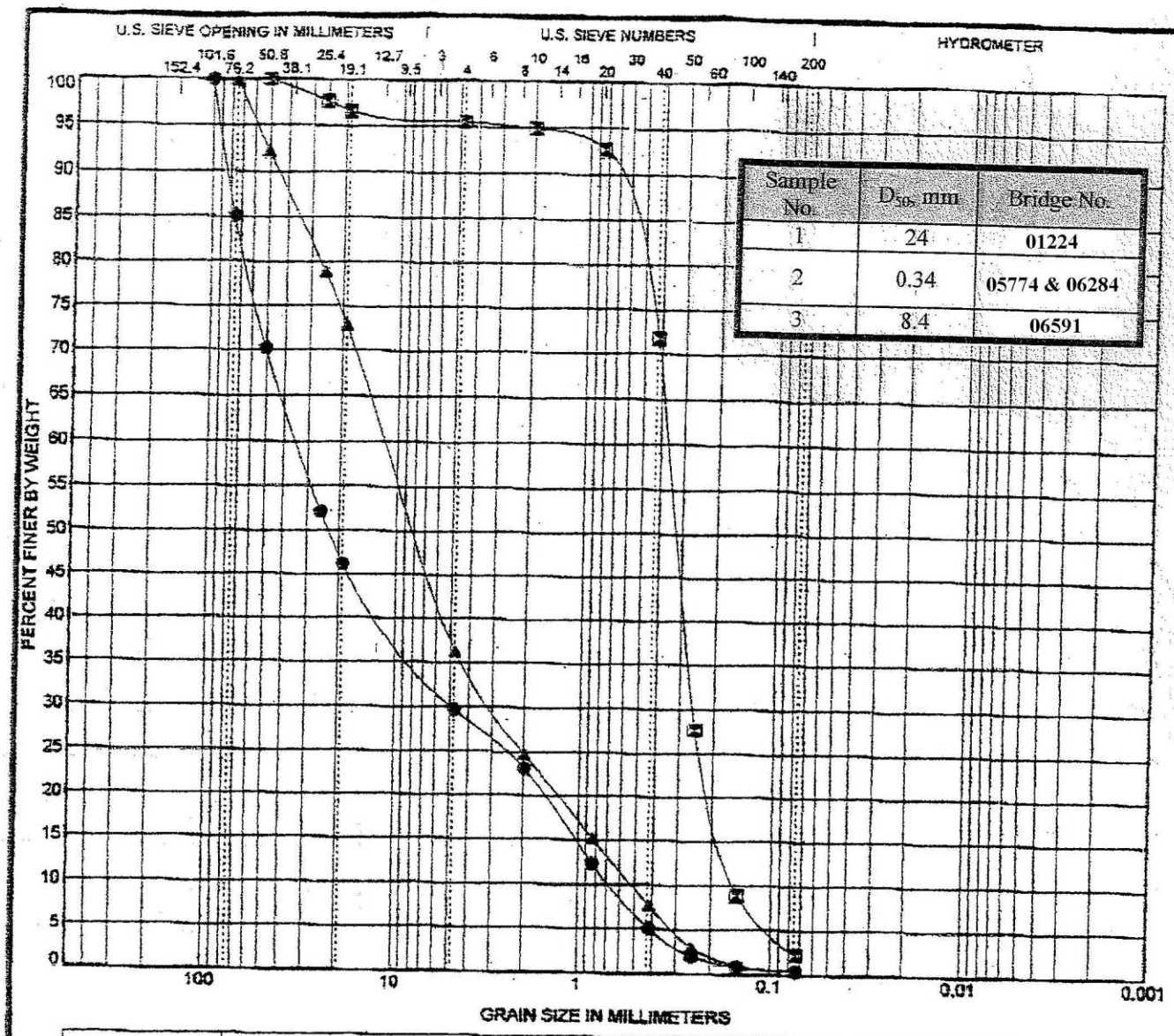
Appendix C:

Geomorphic Characterization
and
Grain Size Distribution

Mad River, Waterbury, CT
Proposed Bridge No. 05774



Geomorphic factors that affect stream stability



Sample No.	D_{50}, mm	Bridge No.
1	24	01224
2	0.34	05774 & 06284
3	8.4	06591

	COBBLES	% GRAVEL			% SAND		% FINES	
		COARSE	MEDIUM	FINE	COARSE	FINE	% SILT	% CLAY
●	14.9	32.4	14.3	14.8	18.0	4.7	0.4	
■	0.0	2.4	1.5	1.1	23.2	69.6	2.2	
▲	0.0	20.8	24.5	29.8	17.0	7.2	0.5	

	Expl. No.	Sample No.	Depth (m)	LL	PL	PI	Water Content (%)	Cc	Cu
●	TP	1					6.2	1.04	51.02
■	TP	2					21.2	1.17	2.38
▲	TP	3					5.6	1.46	22.48

Sample Description

●	Brown coarse to fine GRAVEL, little cobbles, little coarse sand, trace fine sand
■	Light brown coarse to fine SAND, trace coarse to fine gravel, trace silt
▲	Orange brown coarse to fine GRAVEL, little coarse sand, trace fine sand

Remarks:

HALEY & ALDRICH
Glastonbury, Connecticut

I-84 Reconstruction
Waterbury, Connecticut
State Project No.:

GRAIN SIZE DISTRIBUTION

Date: 12/17/2000

File No.: 91313-100

CONN DOT SIEVE 91313B.GPJ US LAB.GDT 12/20/00